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(12) **United States Patent**
Misaka

(10) **Patent No.: US 9,140,905 B2**
(45) **Date of Patent: Sep. 22, 2015**

(54) **VIBRATION PROOF ZOOM LENS AND PHOTOGRAPHING APPARATUS HAVING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 816 days.

(21) Appl. No.: **13/332,742**

(22) Filed: **Dec. 21, 2011**

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(30) **Foreign Application Priority Data**

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Nov. 23, 2011 (KR) 2011-0123237

(51) **Int. Cl.**
G02B 27/64 (2006.01)
G02B 15/173 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 27/646*** (2013.01); ***G02B 15/173*** (2013.01)

(58) **Field of Classification Search**
CPC G02B 15/173; G02B 15/28
USPC 359/554–557, 676–690, 693–706, 359/772–790, 796–797
See application file for complete search history.

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(57) **ABSTRACT**

In a vibration proof zoom lens **100**, a third lens group G**3** has a positive lens **7**, a positive cemented lens **8**, a negative cemented lens **9**, which are arranged in order from an object side. In variable-magnifying from a wide angle limit to a telephoto limit, a clearance between a first lens group G**1** and a second lens group G**2** is increased and at the same time, a clearance between the second lens group G**2** and a third lens groupG**3** is decreased, a focusing from an infinity side to a close side is performed by moving the positive lens **7** toward an image, and a vibration proof is performed by moving the cemented lens **9** in a direction perpendicular to an optical axis to change an image position.

15 Claims, 31 Drawing Sheets

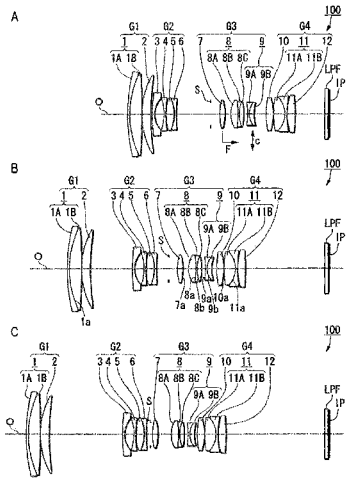

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FIG. 1

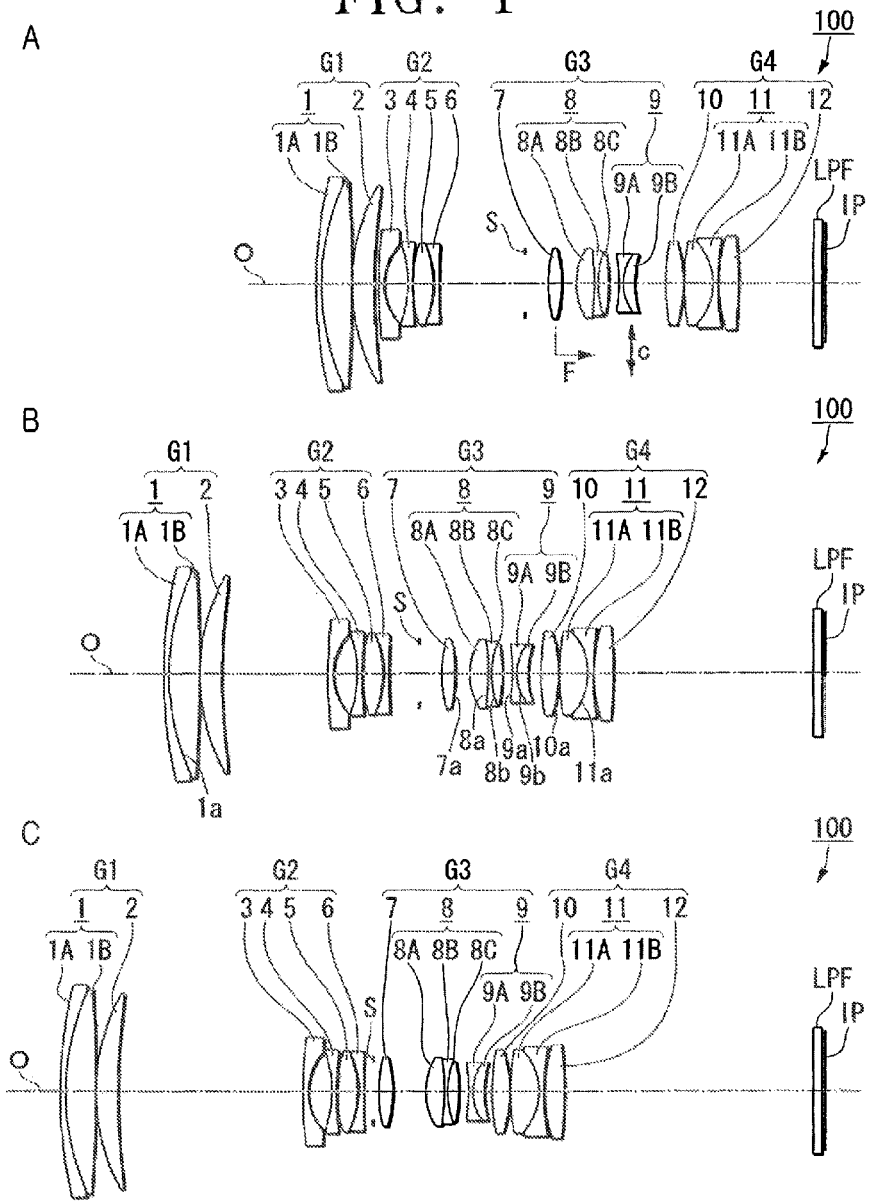

A
100
G1
G2
G3
G4
1
2
3 4 5 6
7
8
9
10
11
12
1A 1B
8A 8B 8C
9A 9B
11A 11B
LPF
IP
S
O
F
c
B
100
G1
G2
G3
G4
1A 1B
8A 8B 8C
9A 9B
11A 11B
LPF
IP
S
O
1a
7a
8a
8b
9a
9b
10a
11a
C
100
G1
G2
G3
G4
1A 1B
8A 8B 8C
9A 9B
11A 11B
LPF
IP
S
O

FIG. 2

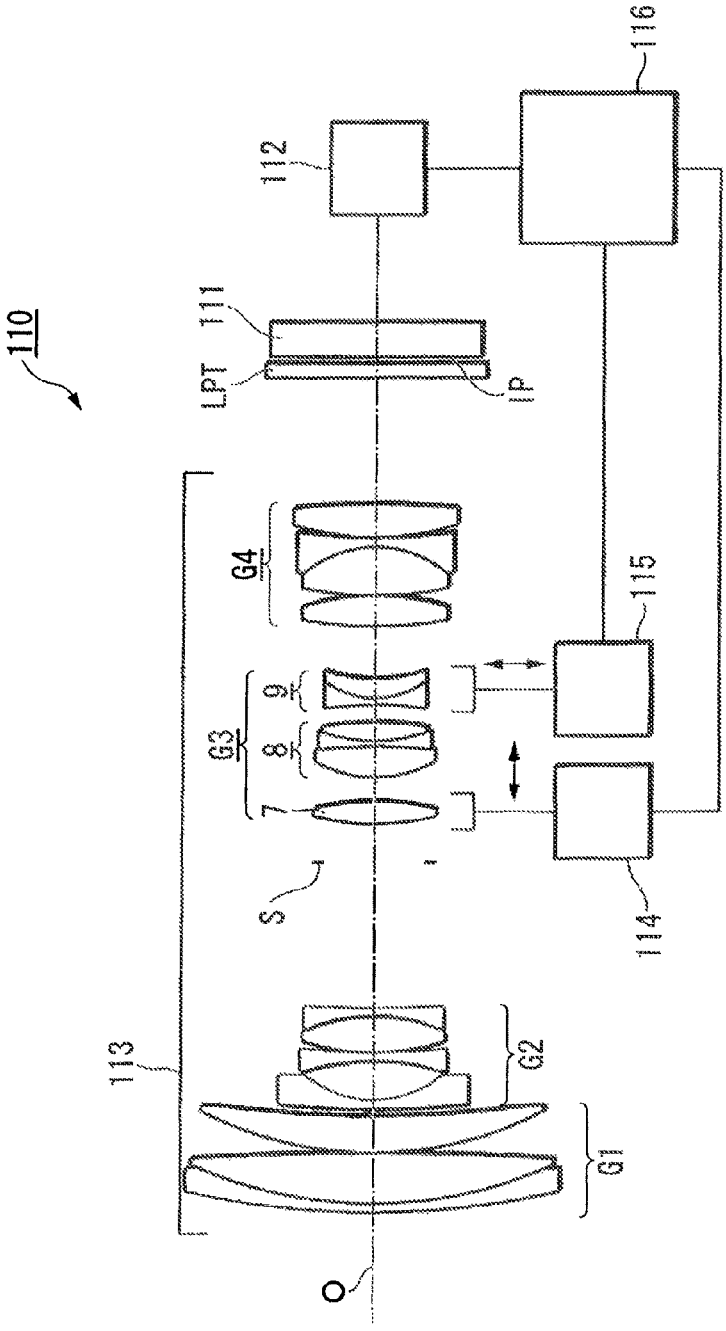


FIG. 3

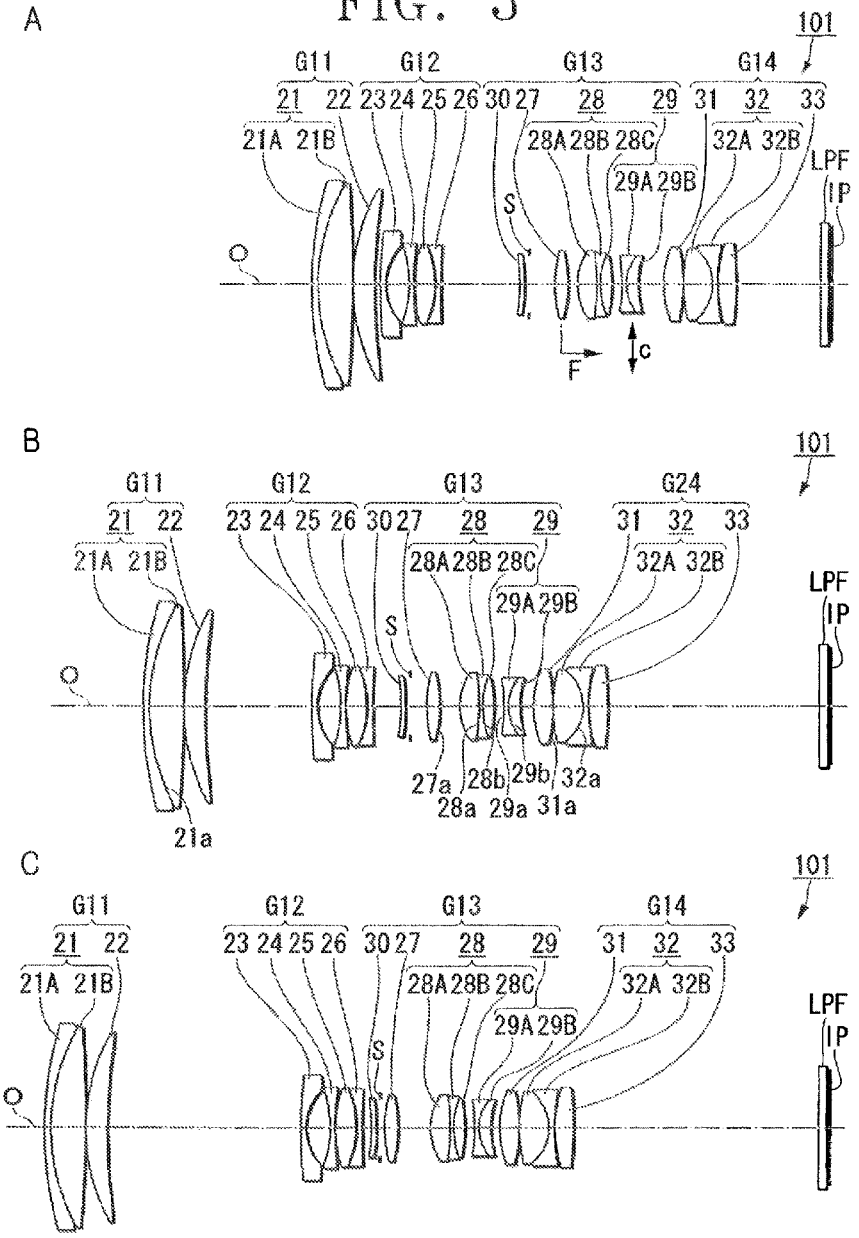

A
101
G11
G12
G13
G14
21 22 23 24 25 26 30 27 28 29 31 32 33
21A 21B
28A 28B 28C
29A 29B
32A 32B
LPF
IP
S
O
F
C
B
101
G11
G12
G13
G24
21 22 23 24 25 26 30 27 28 29 31 32 33
21A 21B
28A 28B 28C
29A 29B
32A 32B
LPF
IP
S
O
21a
27a
28b
29b
32a
28a
29a
31a
C
101
G11
G12
G13
G14
21 22 23 24 25 26 30 27 28 29 31 32 33
21A 21B
28A 28B 28C
29A 29B
32A 32B
LPF
IP
S
O

FIG. 4

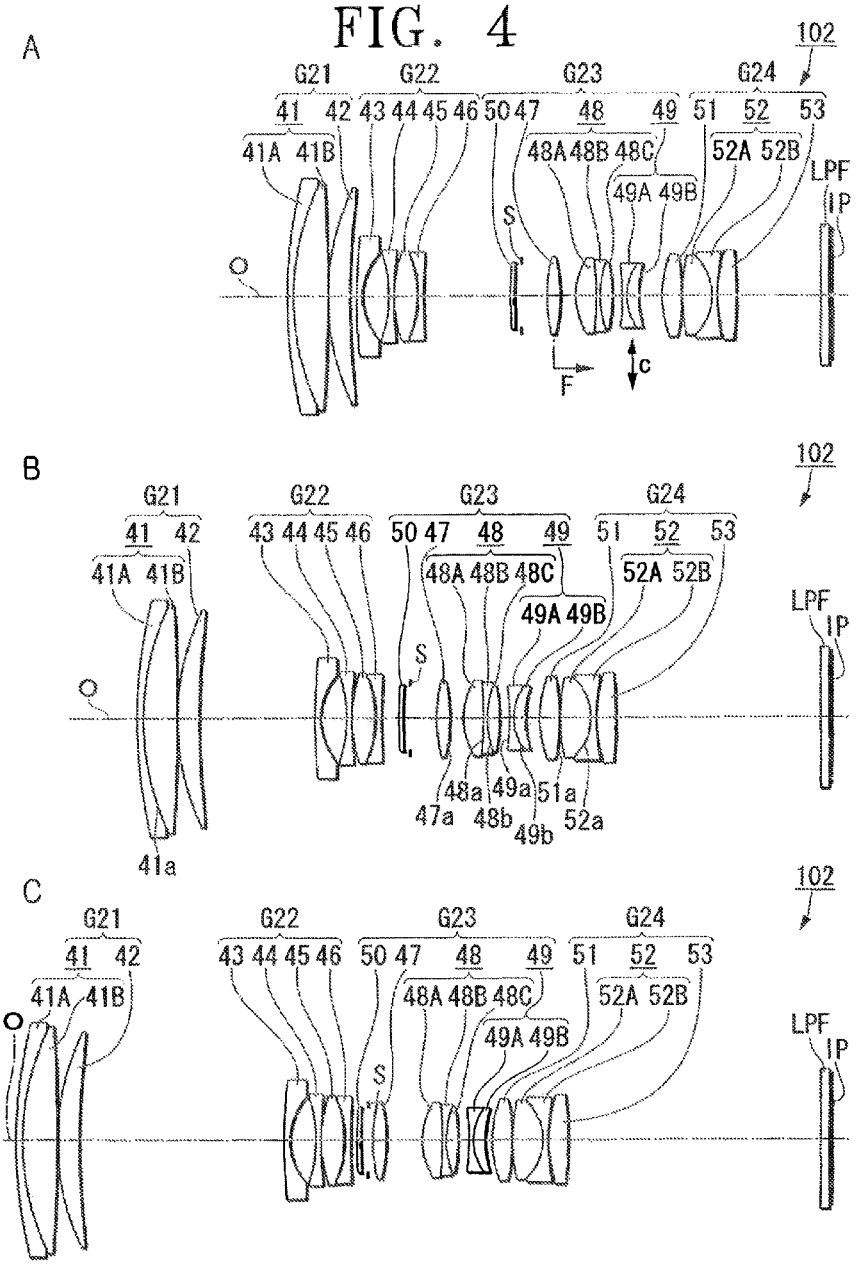

A
102
G21
G22
G23
G24
41 42 43 44 45 46 50 47 48 49 51 52 53
41A 41B
48A 48B 48C
49A 49B
52A 52B
LPF
IP
S
O
F
c
B
102
G21
G22
G23
G24
41 42 43 44 45 46 50 47 48 49 51 52 53
41A 41B
48A 48B 48C
49A 49B
52A 52B
LPF
IP
S
O
41a
47a
48a
48b
49a
49b
51a
52a
C
102
G21
G22
G23
G24
41 42 43 44 45 46 50 47 48 49 51 52 53
41A 41B
48A 48B 48C
49A 49B
52A 52B
LPF
IP
S
O

FIG. 5

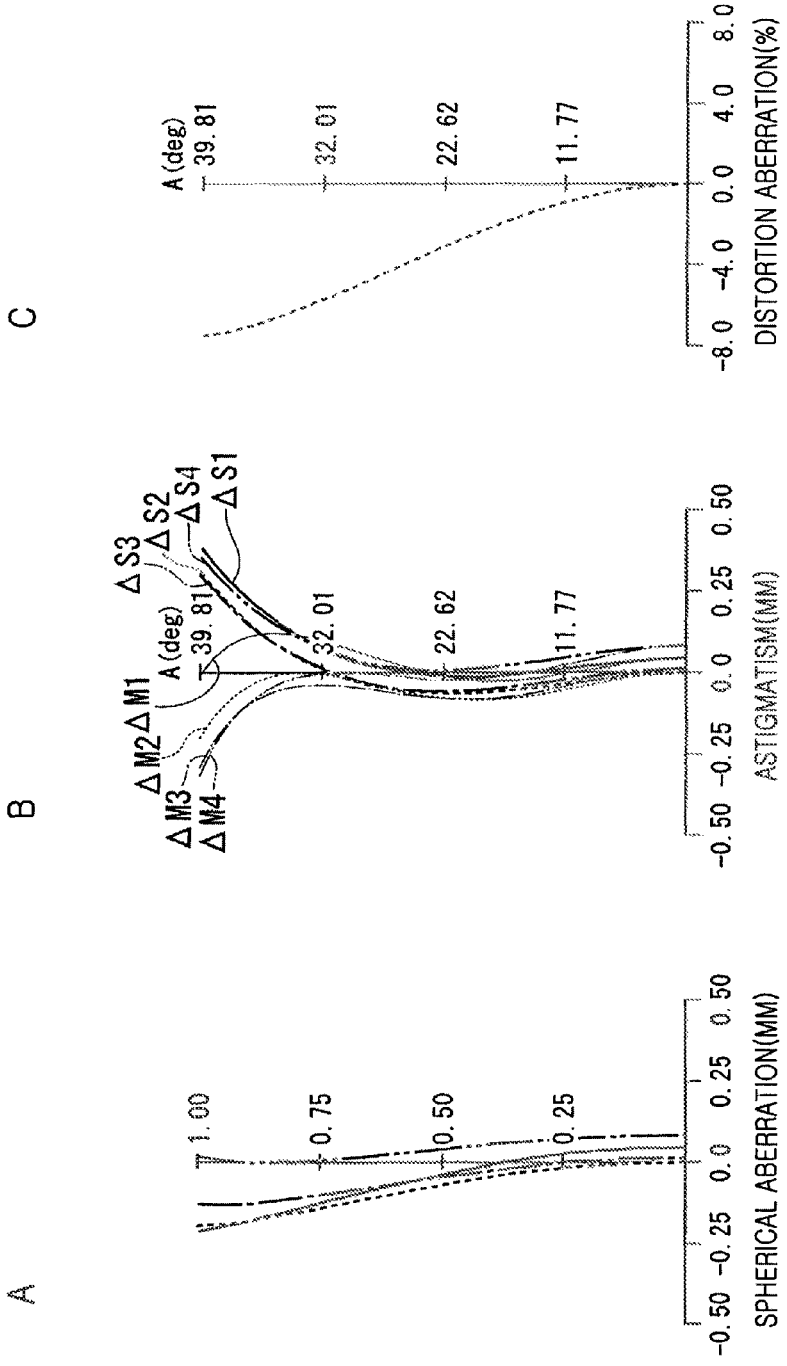

A
1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
SPHERICAL ABERRATION(MM)
B
ΔS3
ΔS2
ΔS4
ΔS1
ΔM2
ΔM1
A(deg)
39.81
32.01
22.62
11.77
ΔM3
ΔM4
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
C
A(deg)
39.81
32.01
22.62
11.77
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 6

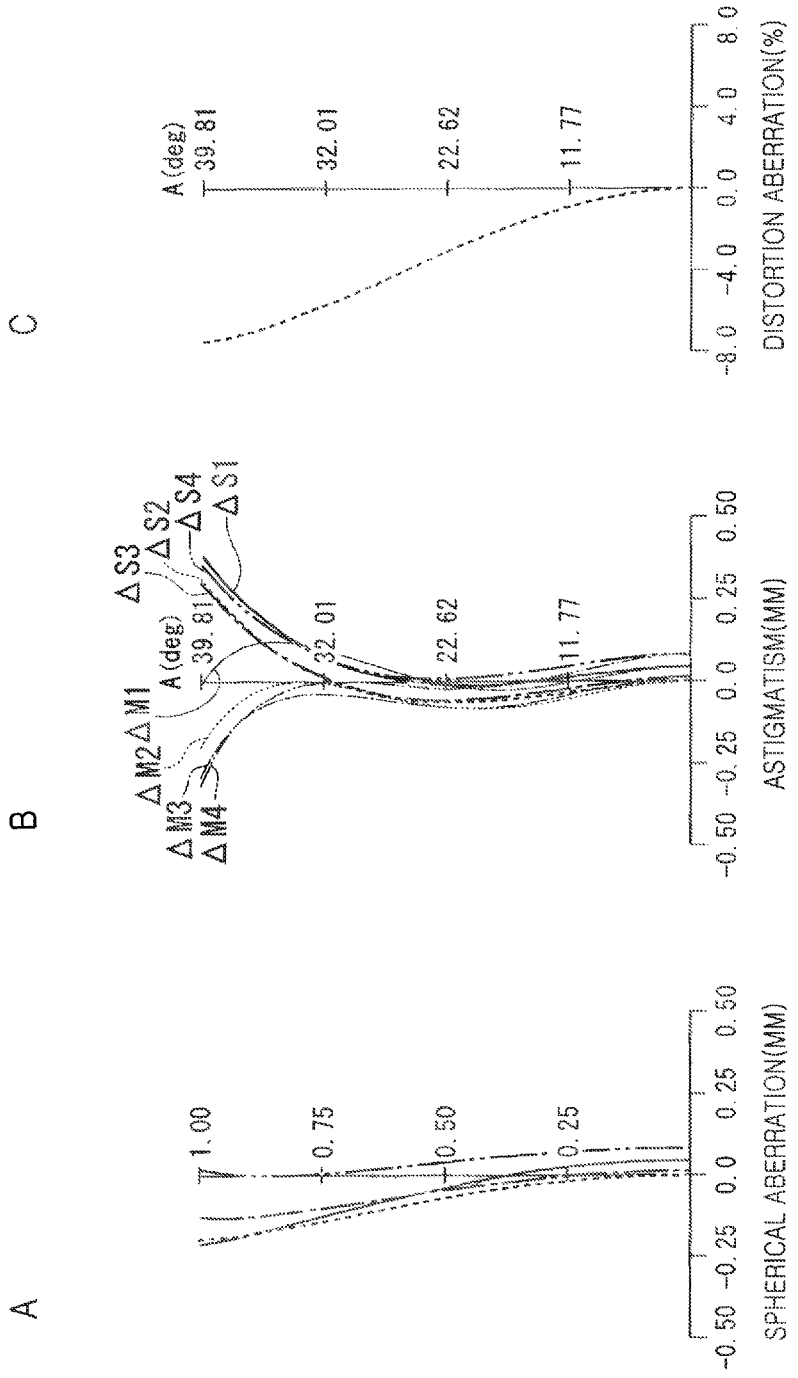

A
B
C
SPHERICAL ABERRATION(MM)
-0.50 -0.25 0.0 0.25 0.50
1.00
0.75
0.50
0.25
ASTIGMATISM(MM)
-0.50 -0.25 0.0 0.25 0.50
ΔS3
ΔS2
ΔS4
ΔS1
ΔM2
ΔM1
ΔM3
ΔM4
A (deg)
39.81
32.01
22.62
11.77
DISTORTION ABERRATION(%)
-8.0 -4.0 0.0 4.0 8.0

FIG. 7

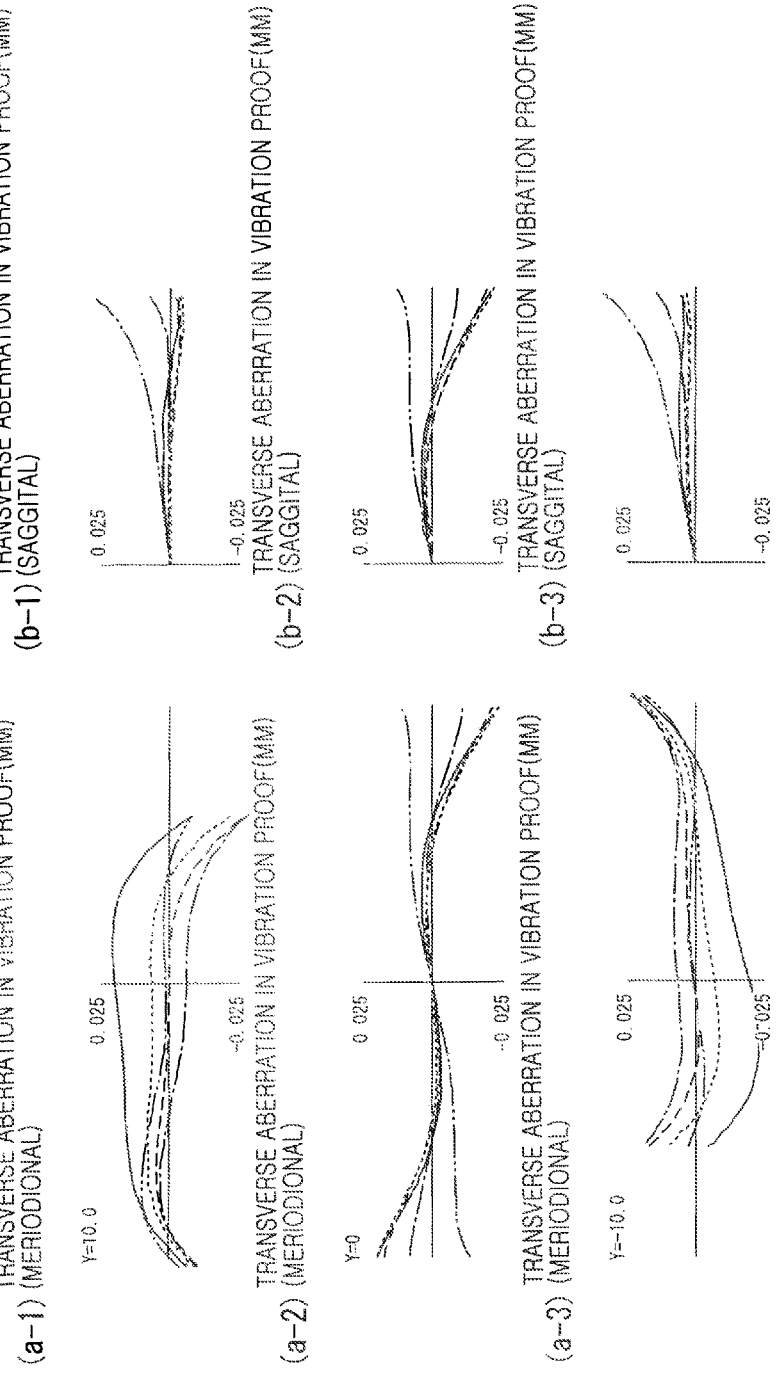

TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(a-1) (MERIODIONAL)
Y=10.0
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(a-2) (MERIODIONAL)
Y=0
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(a-3) (MERIODIONAL)
Y=-10.0
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(b-1) (SAGGITAL)
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(b-2) (SAGGITAL)
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(b-3) (SAGGITAL)
0.025
-0.025

FIG. 8

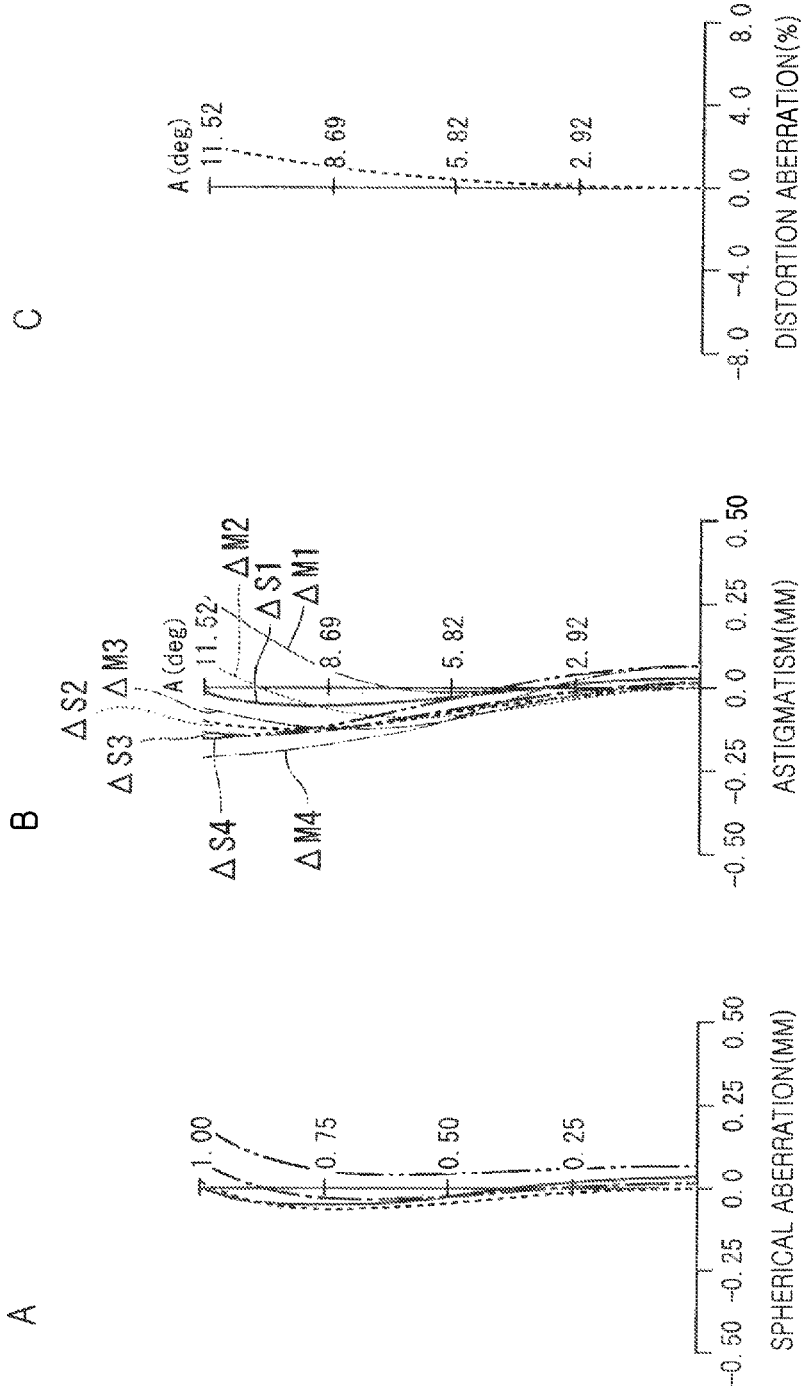

A
B
C
SPHERICAL ABERRATION(MM)
-0.50 -0.25 0.0 0.25 0.50
1.00
0.75
0.50
0.25
ASTIGMATISM(MM)
-0.50 -0.25 0.0 0.25 0.50
ΔS2
ΔM3
ΔS3
ΔS4
ΔM2
ΔS1
ΔM1
ΔM4
ω(deg)
11.52
8.69
5.82
2.92
DISTORTION ABERRATION(%)
-8.0 -4.0 0.0 4.0 8.0

FIG. 9

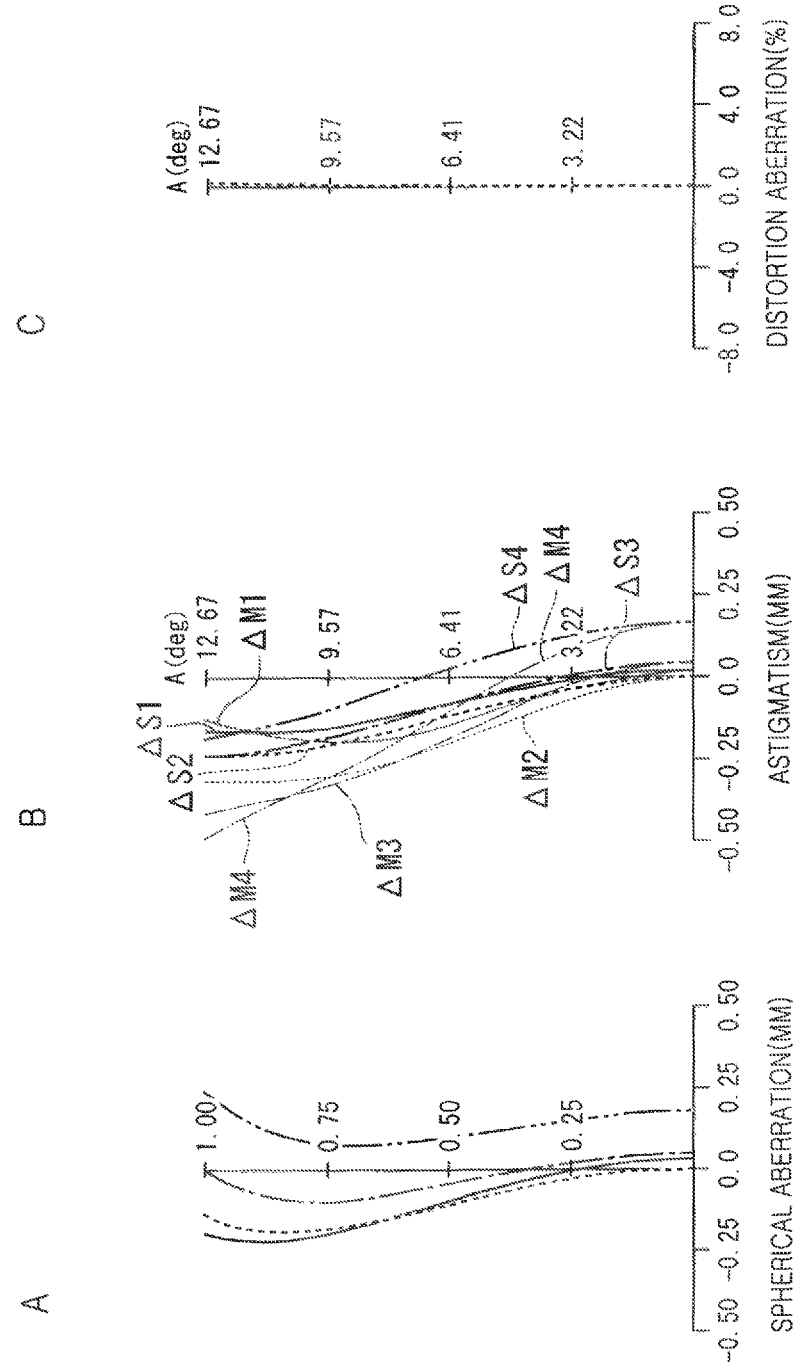

A
B
C
1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
SPHERICAL ABERRATION(MM)
A(deg)
12.67
9.57
6.41
3.22
ΔS1
ΔS2
ΔM1
ΔM2
ΔM3
ΔM4
ΔS3
ΔS4
ΔM4
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
A(deg)
12.67
9.57
6.41
3.22
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 10

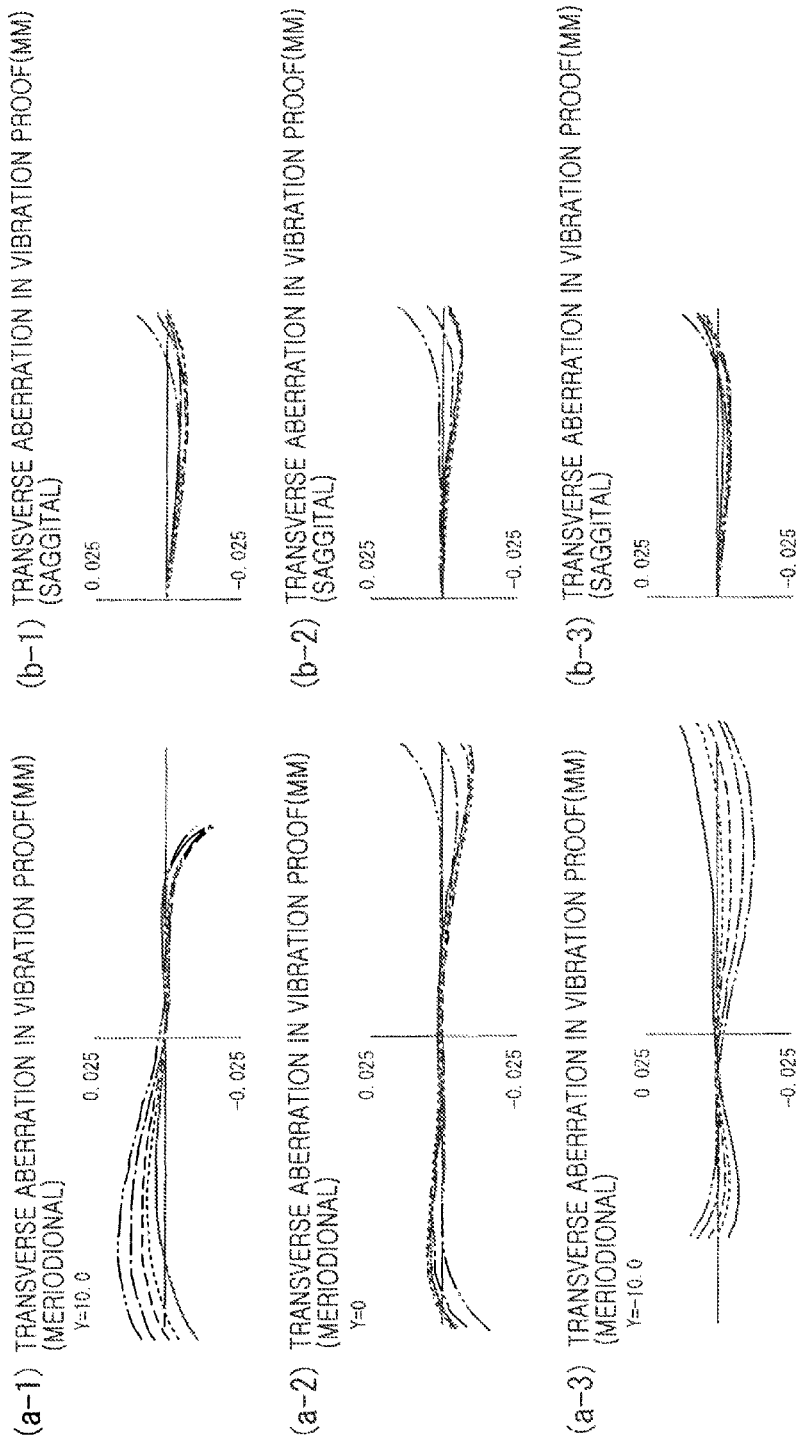

(a-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=10.0
0.025
-0.025
(b-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=0
0.025
-0.025
(b-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=-10.0
0.025
-0.025
(b-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025

FIG. 11

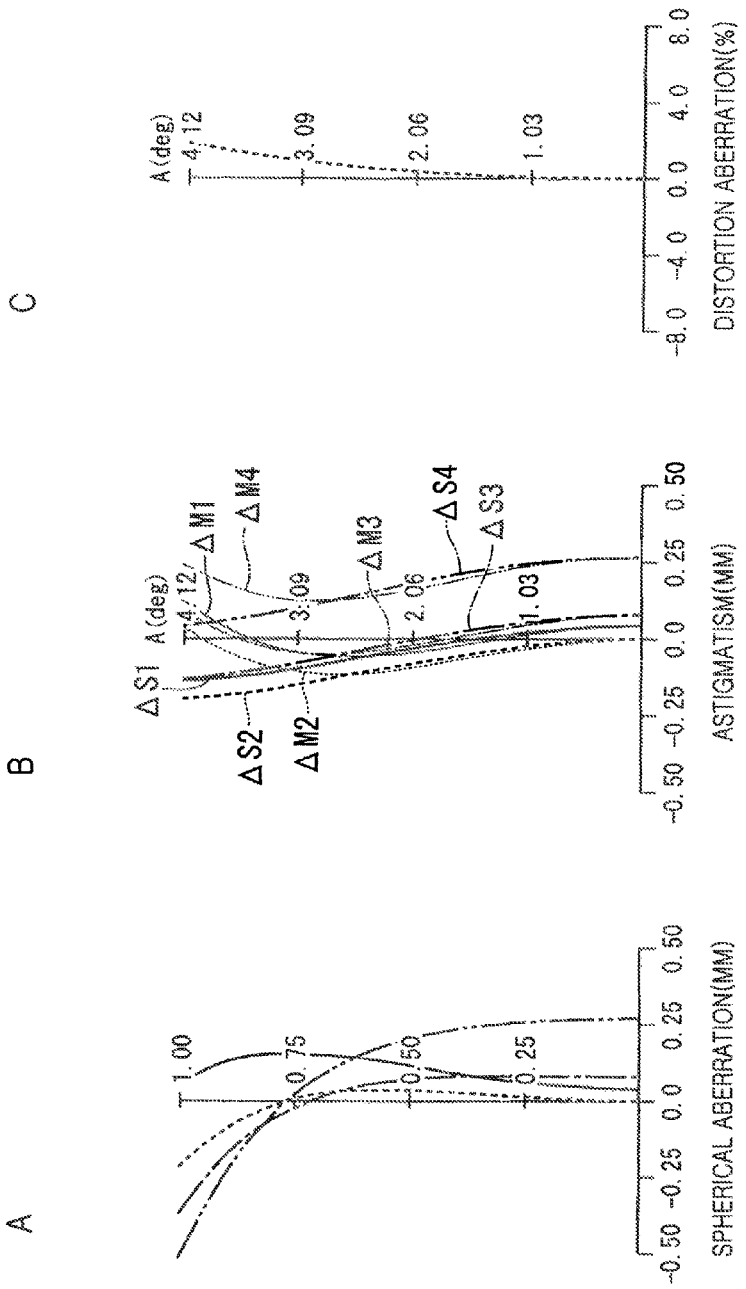

A
B
C
T 1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
SPHERICAL ABERRATION(MM)
ΔS1
ΔS2
ΔM1
ΔM2
ΔM3
ΔM4
ΔS3
ΔS4
A(deg)
4.12
3.09
2.06
1.03
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
A(deg)
4.12
3.09
2.06
1.03
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 12

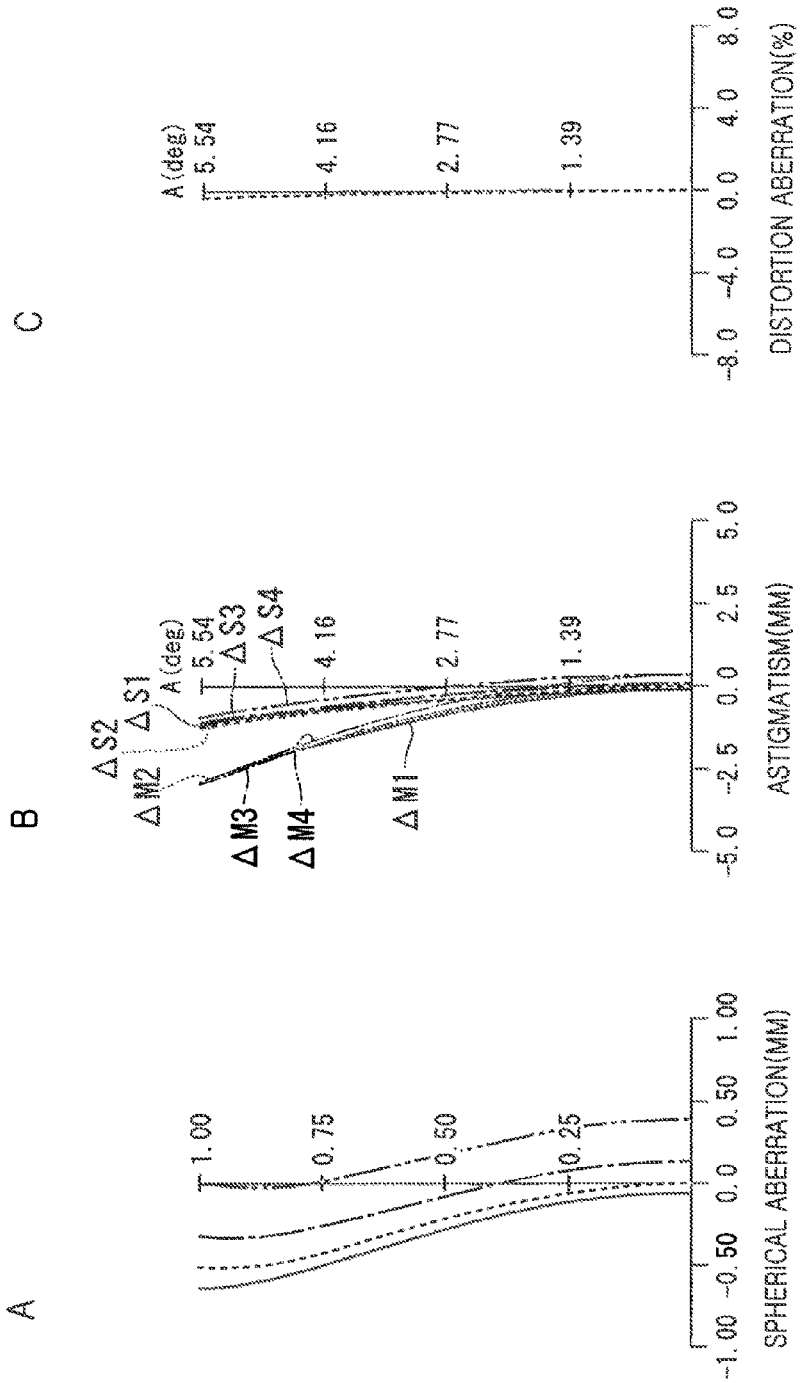

A
B
C
1.00
0.75
0.50
0.25
-1.00 -0.50 0.0 0.50 1.00
SPHERICAL ABERRATION(MM)
ΔS2
ΔS1
A(deg)
5.54
ΔS3
ΔS4
4.16
2.77
1.39
ΔM2
ΔM3
ΔM4
ΔM1
-5.0 -2.5 0.0 2.5 5.0
ASTIGMATISM(MM)
A(deg)
5.54
4.16
2.77
1.39
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 13

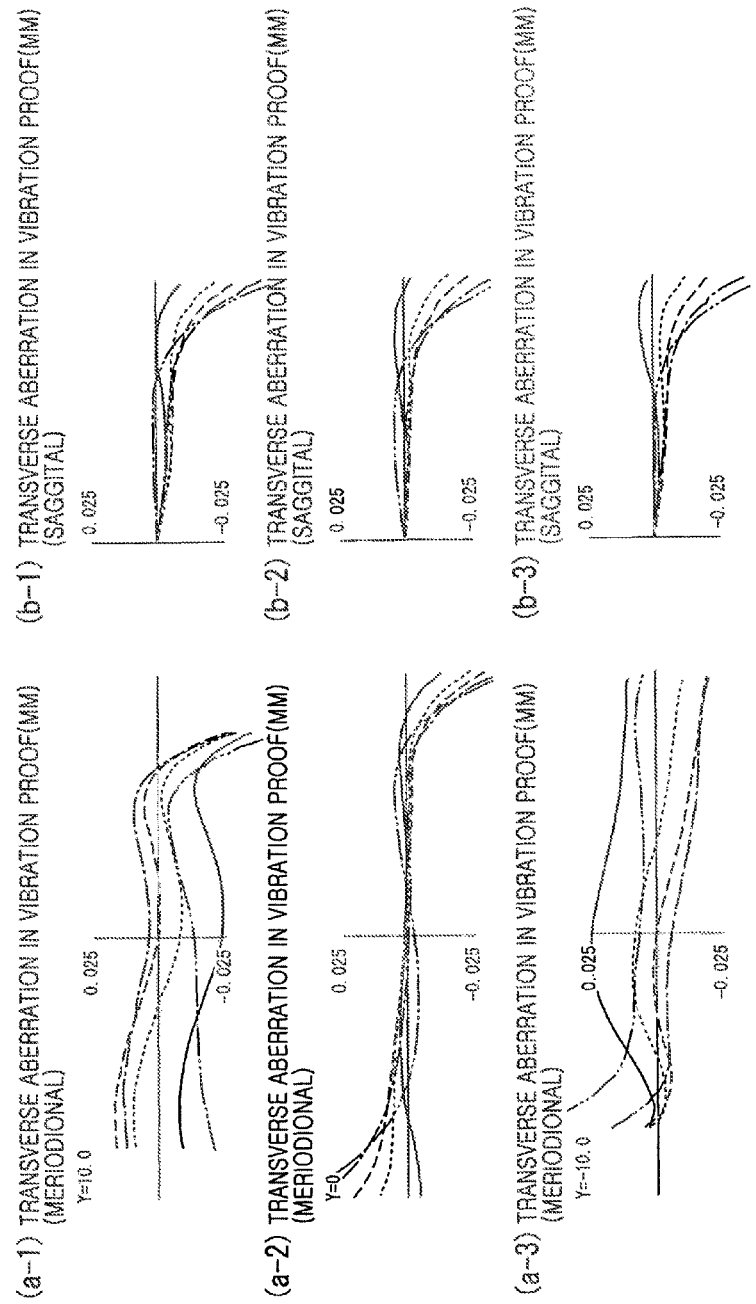

(a-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=10.0
0.025
-0.025
(a-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=0
0.025
-0.025
(a-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=-10.0
0.025
-0.025
(b-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(b-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(b-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025

FIG. 14

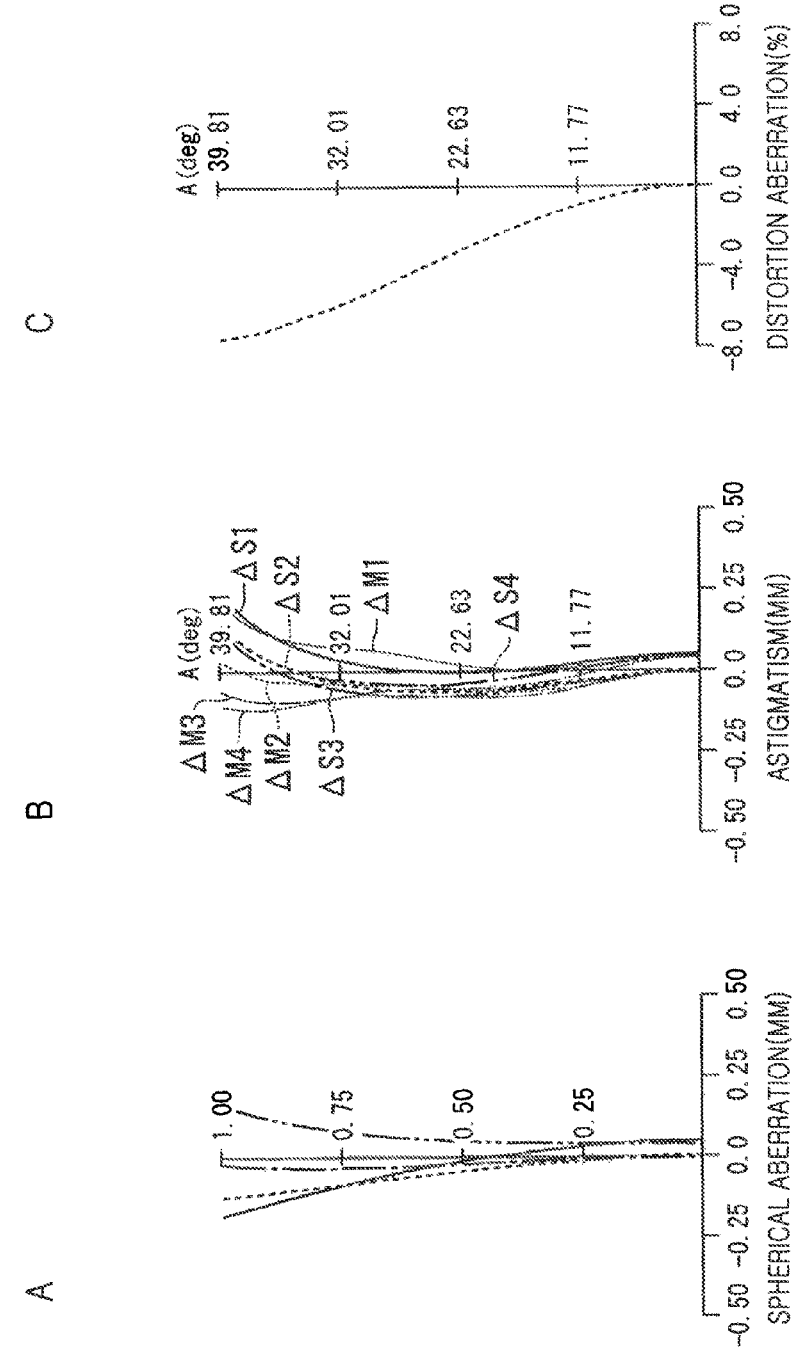

A
1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
SPHERICAL ABERRATION(MM)
B
ΔM3
ΔM4
ΔM2
ΔS3
A(deg)
39.81
32.01
22.63
11.77
ΔS1
ΔS2
ΔM1
ΔS4
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
C
A(deg)
39.81
32.01
22.63
11.77
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 15

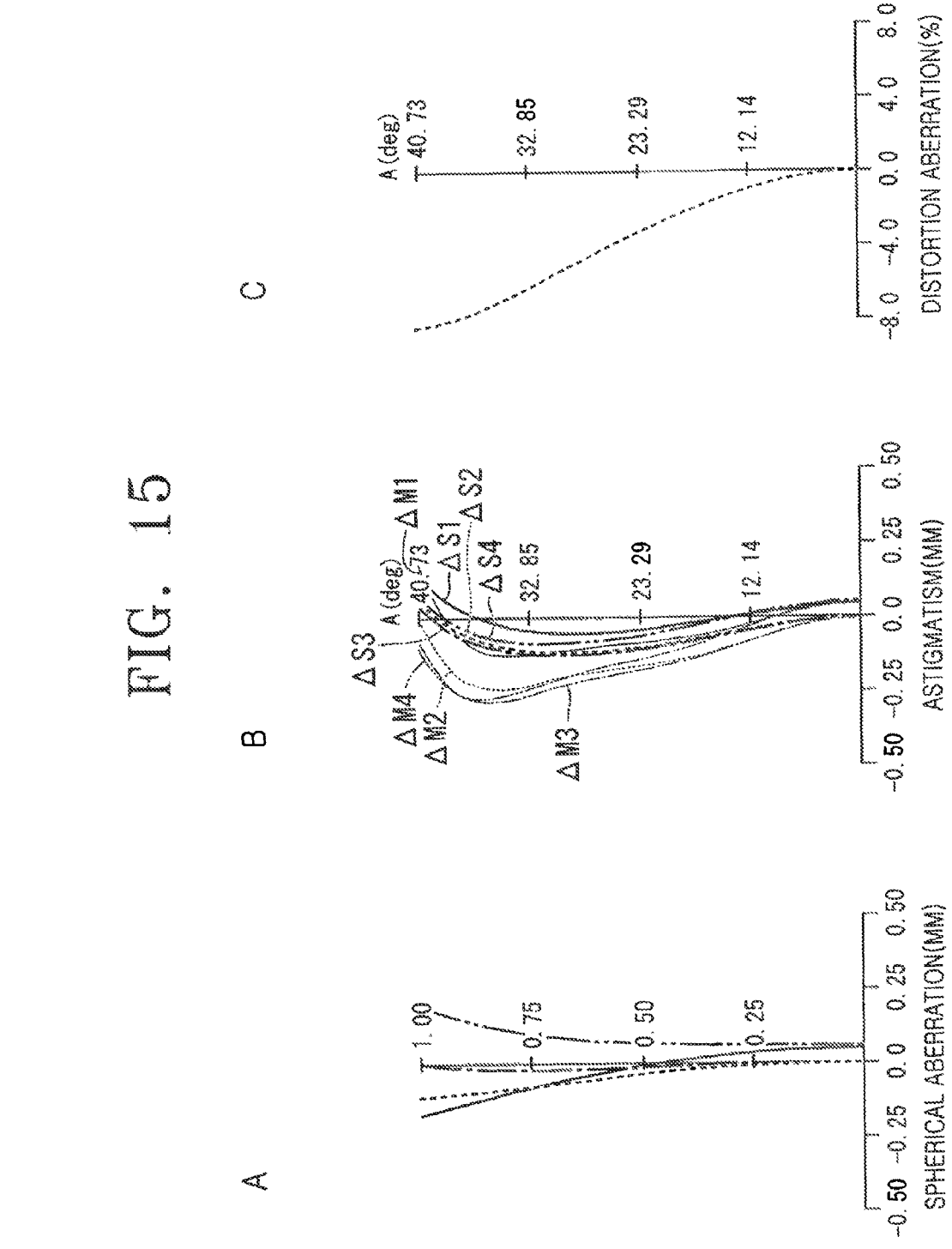

A
B
C
SPHERICAL ABERRATION(MM)
1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
ΔS3
ΔM4
ΔM2
ΔM3
ΔM1
ΔS1
ΔS2
ΔS4
A (deg)
40.73
32.85
23.29
12.14
-0.50 -0.25 0.0 0.25 0.50
DISTORTION ABERRATION(%)
-8.0 -4.0 0.0 4.0 8.0

FIG. 16

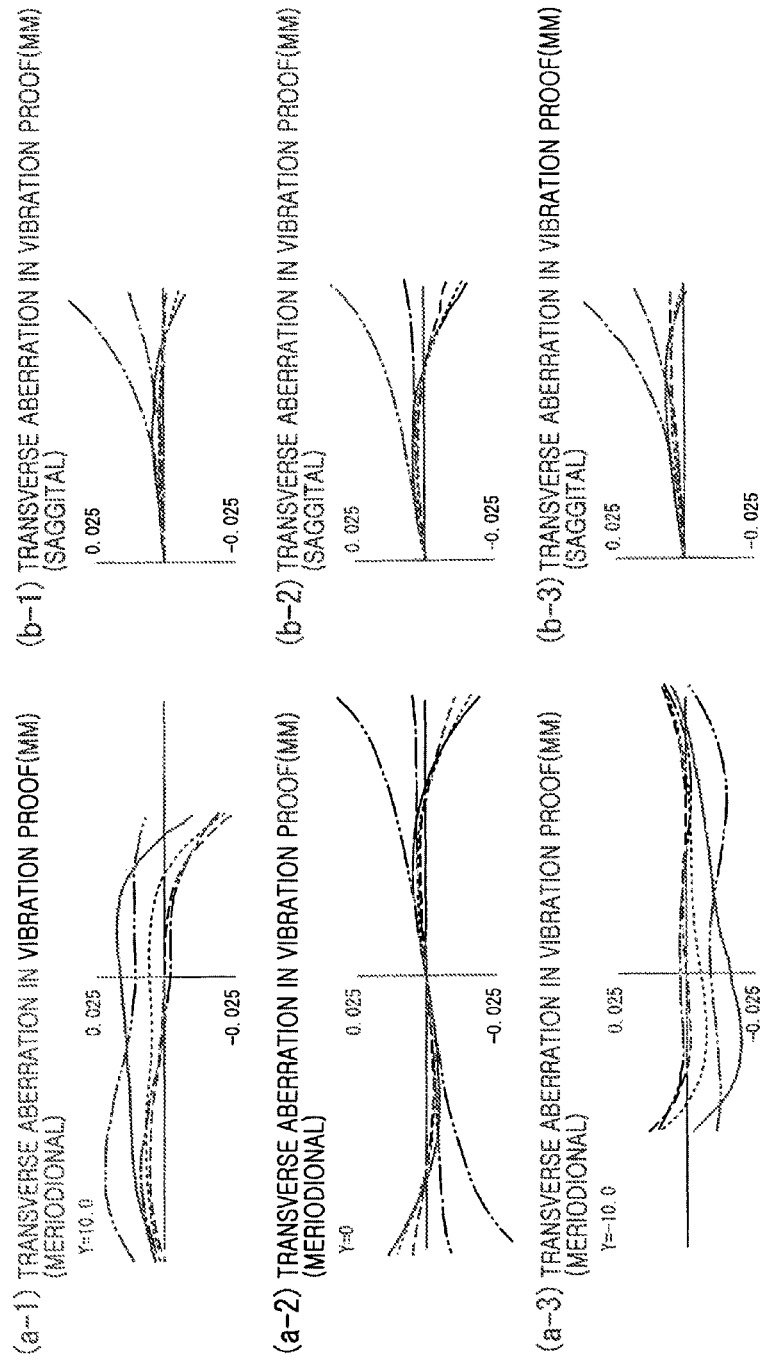

(a-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=10.0
0.025
-0.025
(b-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=0
0.025
-0.025
(b-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=-10.0
0.025
-0.025
(b-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025

FIG. 17

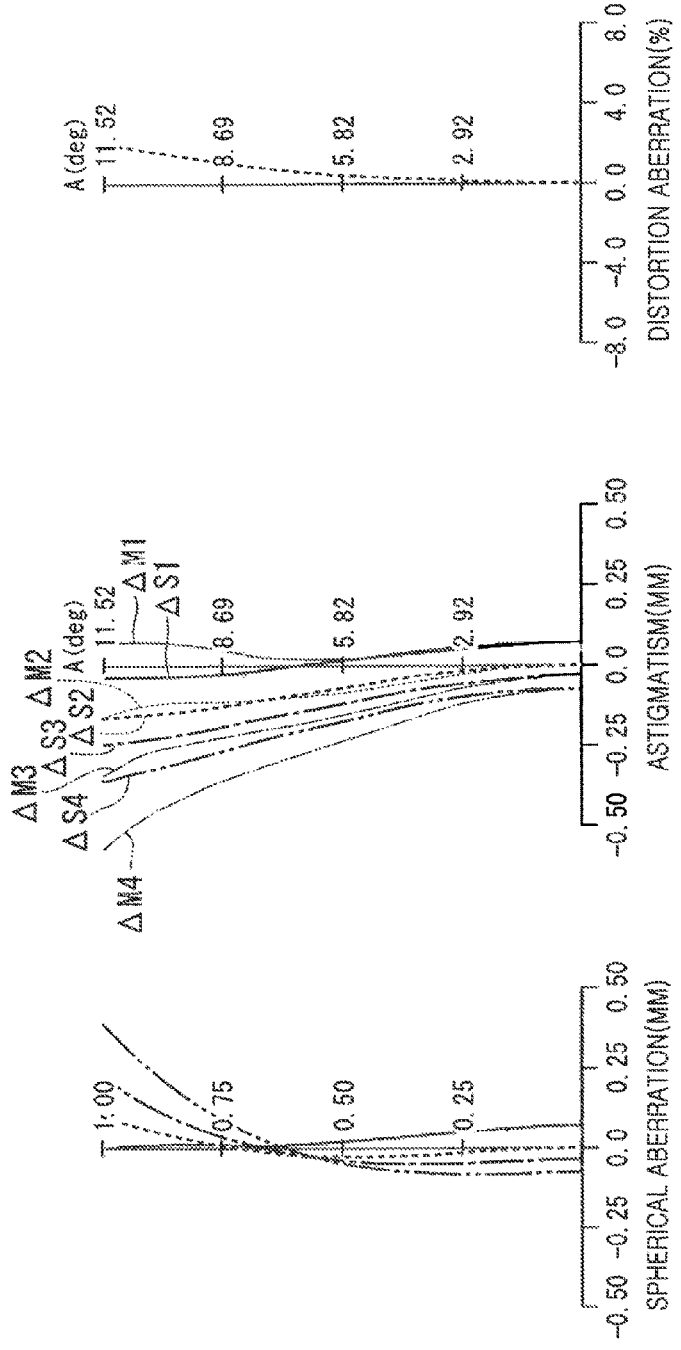

A
B
C
1.00
0.75
0.50
0.25
SPHERICAL ABERRATION(MM)
-0.50 -0.25 0.0 0.25 0.50
ΔM1
ΔS1
ΔM2
ΔS2
ΔS3
ΔM3
ΔS4
ΔM4
A(deg)
11.52
8.69
5.82
2.92
ASTIGMATISM(MM)
-0.50 -0.25 0.0 0.25 0.50
A(deg)
11.52
8.69
5.82
2.92
DISTORTION ABERRATION(%)
-8.0 -4.0 0.0 4.0 8.0

FIG. 18

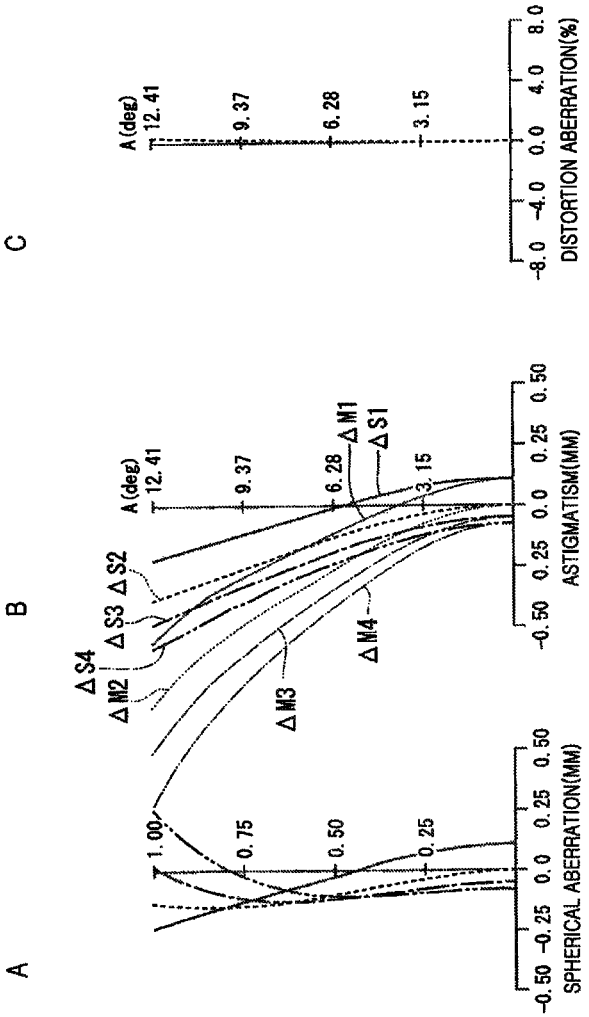

A
B
C
SPHERICAL ABERRATION(MM)
-0.50 -0.25 0.0 0.25 0.50
1.00
0.75
0.50
0.25
ASTIGMATISM(MM)
-0.50 -0.25 0.0 0.25 0.50
A(deg)
12.41
9.37
6.28
3.15
ΔS4
ΔM2
ΔS3
ΔS2
ΔM3
ΔM4
ΔM1
ΔS1
DISTORTION ABERRATION(%)
-8.0 -4.0 0.0 4.0 8.0
A(deg)
12.41
9.37
6.28
3.15

FIG. 19

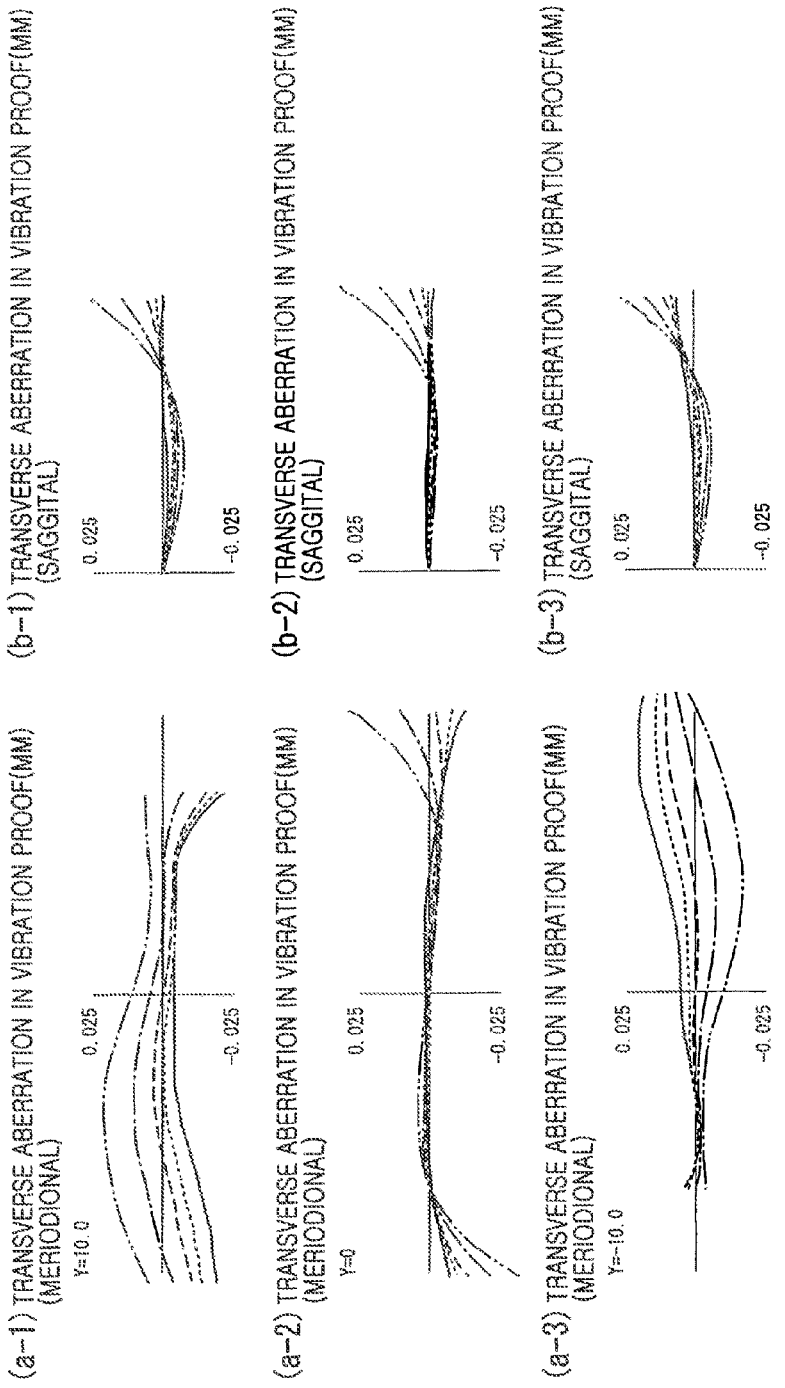

(a-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=10.0
0.025
-0.025
(b-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=0
0.025
-0.025
(b-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=-10.0
0.025
-0.025
(b-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025

FIG. 20

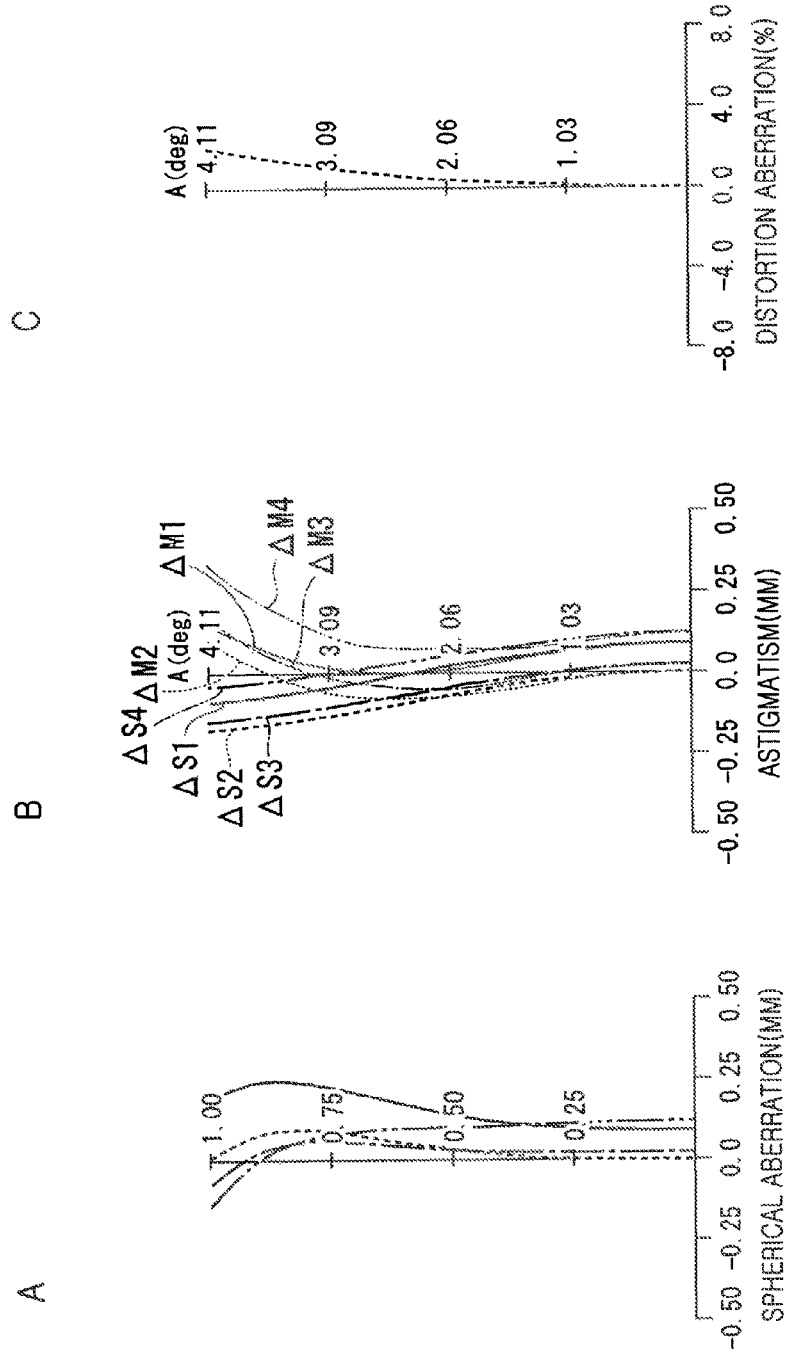

A
B
C
SPHERICAL ABERRATION(MM)
-0.50 -0.25 0.0 0.25 0.50
1.00
0.75
0.50
0.25
ASTIGMATISM(MM)
-0.50 -0.25 0.0 0.25 0.50
ΔS1
ΔS2
ΔS3
ΔS4
ΔM1
ΔM2
ΔM3
ΔM4
A(deg)
4.11
3.09
2.06
1.03
DISTORTION ABERRATION(%)
-8.0 -4.0 0.0 4.0 8.0
A(deg)
4.11
3.09
2.06
1.03

FIG. 21

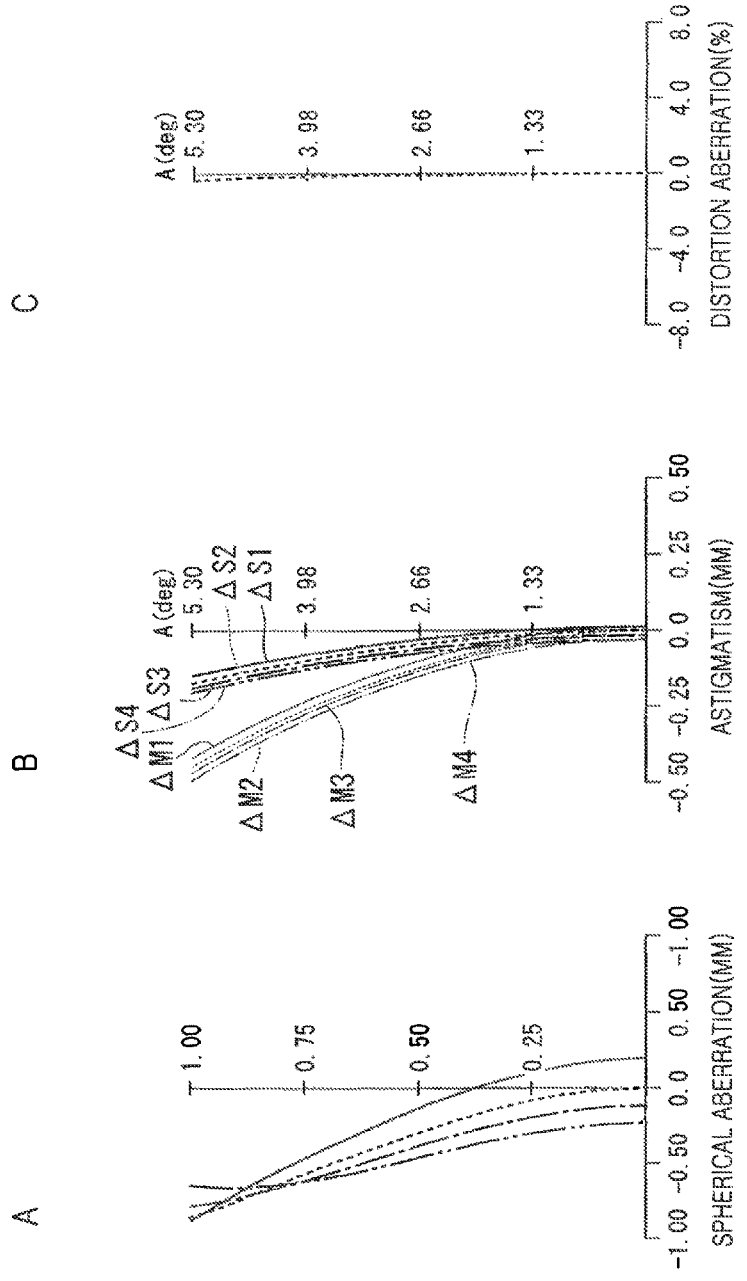

A
1.00
0.75
0.50
0.25
-1.00 -0.50 0.0 0.50 -1.00
SPHERICAL ABERRATION(MM)
B
ΔS4
ΔM1
ΔS3
A(deg)
5.30
ΔS2
ΔS1
3.98
2.66
1.33
ΔM2
ΔM3
ΔM4
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
C
A(deg)
5.30
3.98
2.66
1.33
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 22

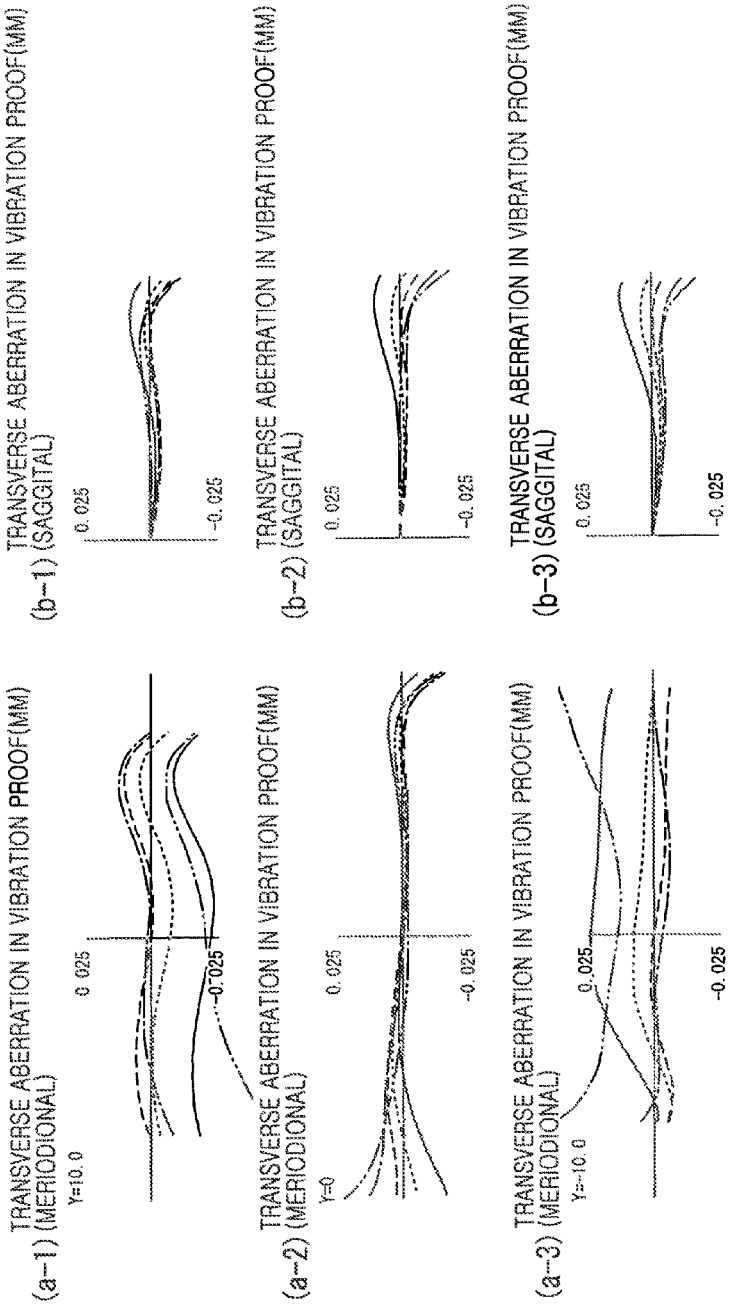

TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(a-1) (MERIODIONAL)
Y=10.0
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(a-2) (MERIODIONAL)
Y=0
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(a-3) (MERIODIONAL)
Y=-10.0
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(b-1) (SAGGITAL)
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(b-2) (SAGGITAL)
0.025
-0.025
TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(b-3) (SAGGITAL)
0.025
-0.025

FIG. 23

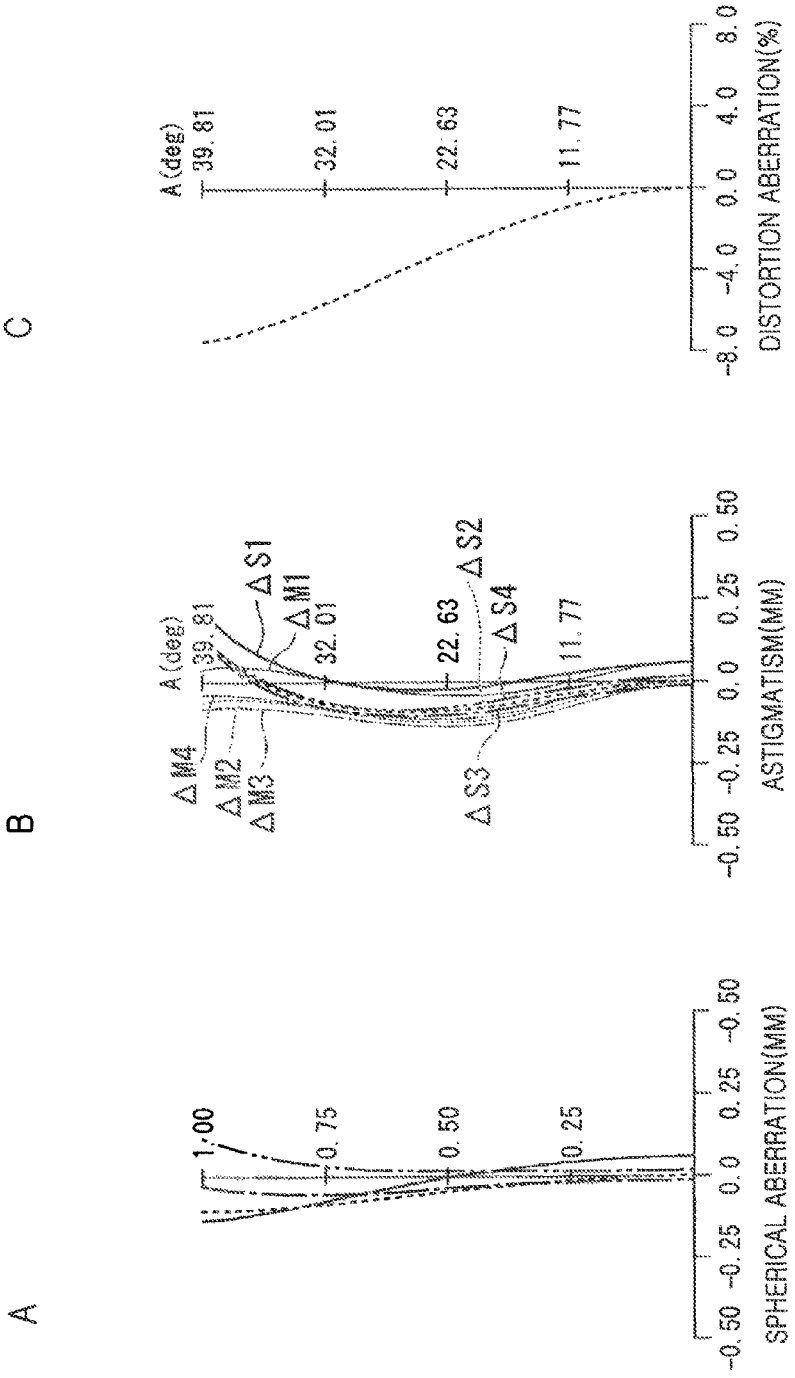

A
1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
SPHERICAL ABERRATION(MM)
B
A(deg)
39.81
32.01
22.63
11.77
ΔM4
ΔM2
ΔM3
ΔS1
ΔM1
ΔS2
ΔS4
ΔS3
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
C
A(deg)
39.81
32.01
22.63
11.77
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 24

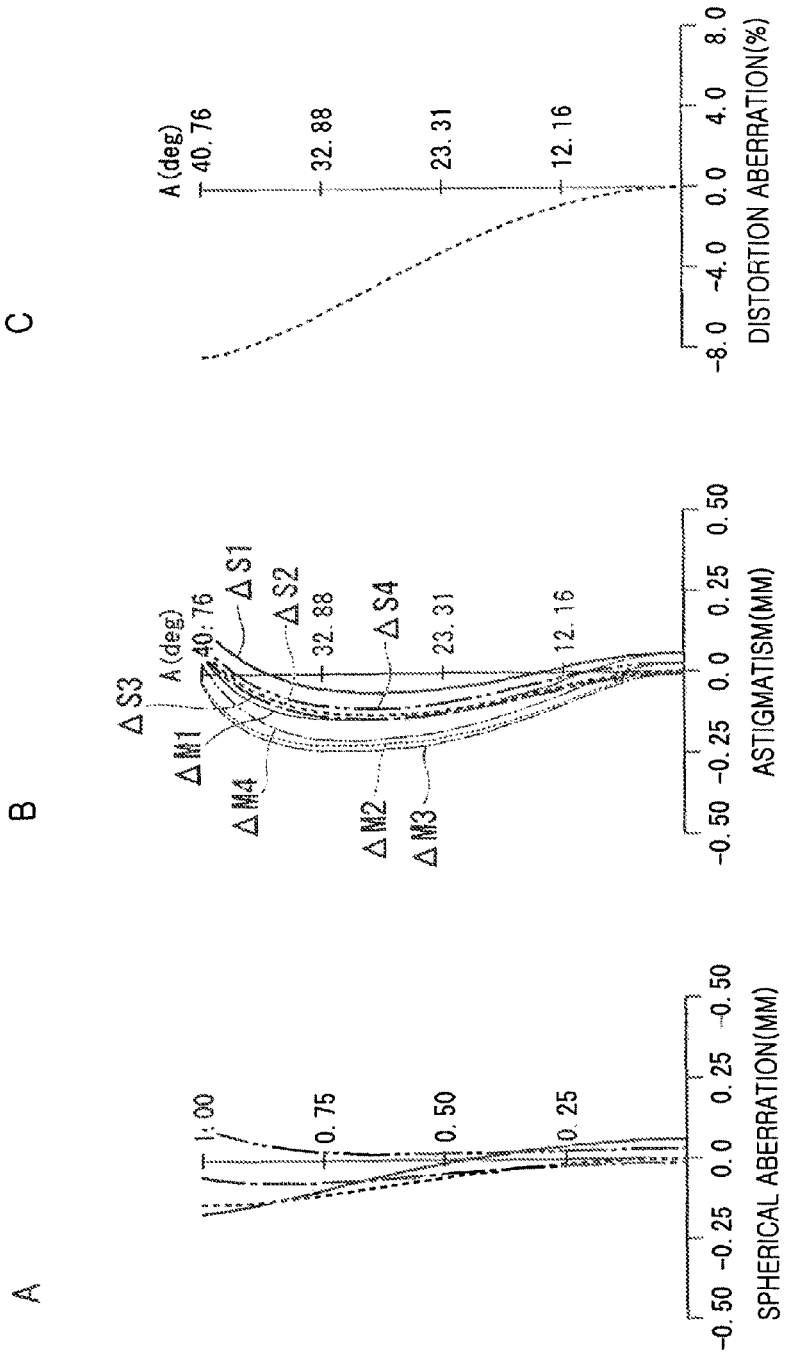

A
B
C
SPHERICAL ABERRATION(MM)
1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
ΔS3
ΔM1
ΔM4
ΔS1
ΔS2
ΔS4
ΔM2
ΔM3
A(deg)
40.76
32.88
23.31
12.16
-0.50 -0.25 0.0 0.25 0.50
DISTORTION ABERRATION(%)
-8.0 -4.0 0.0 4.0 8.0

FIG. 25

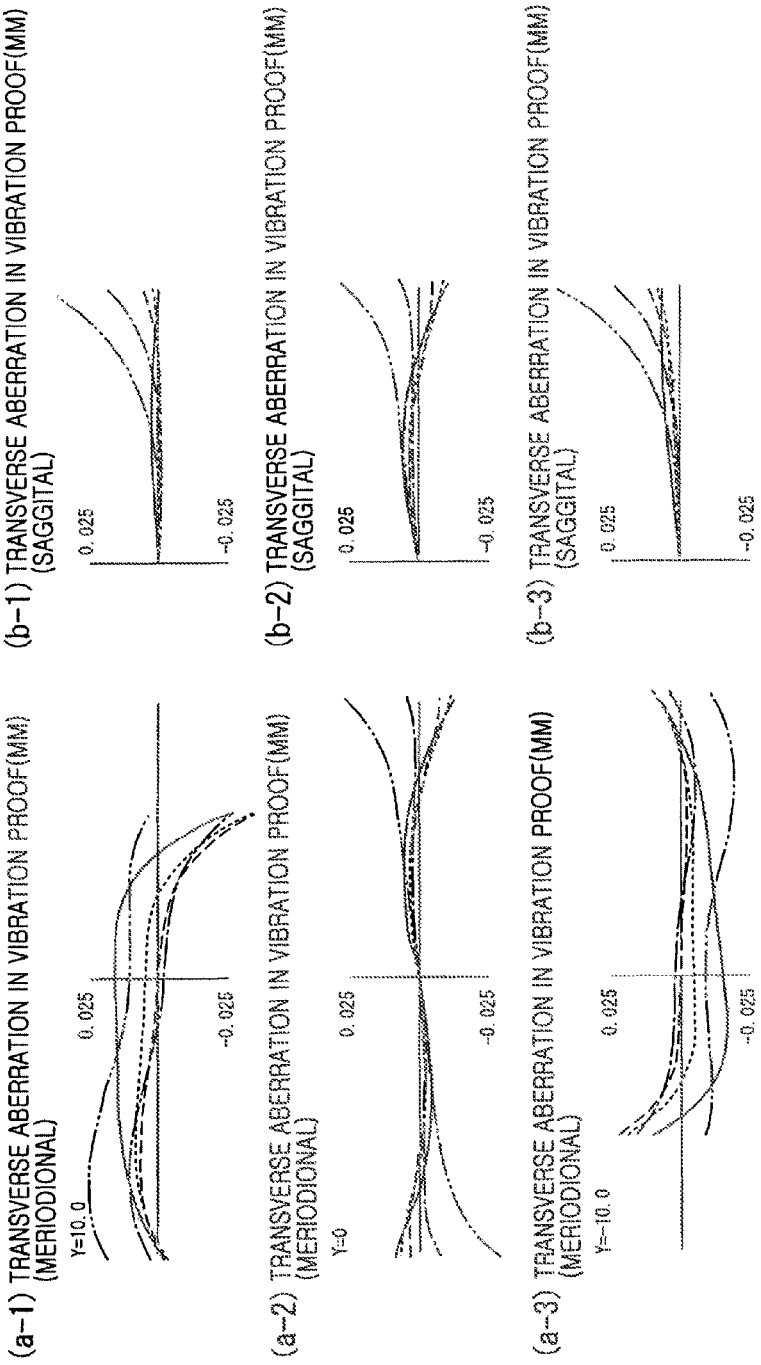

(a-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=10.0
0.025
-0.025
(b-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=0
0.025
-0.025
(b-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(a-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=-10.0
0.025
-0.025
(b-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025

FIG. 26

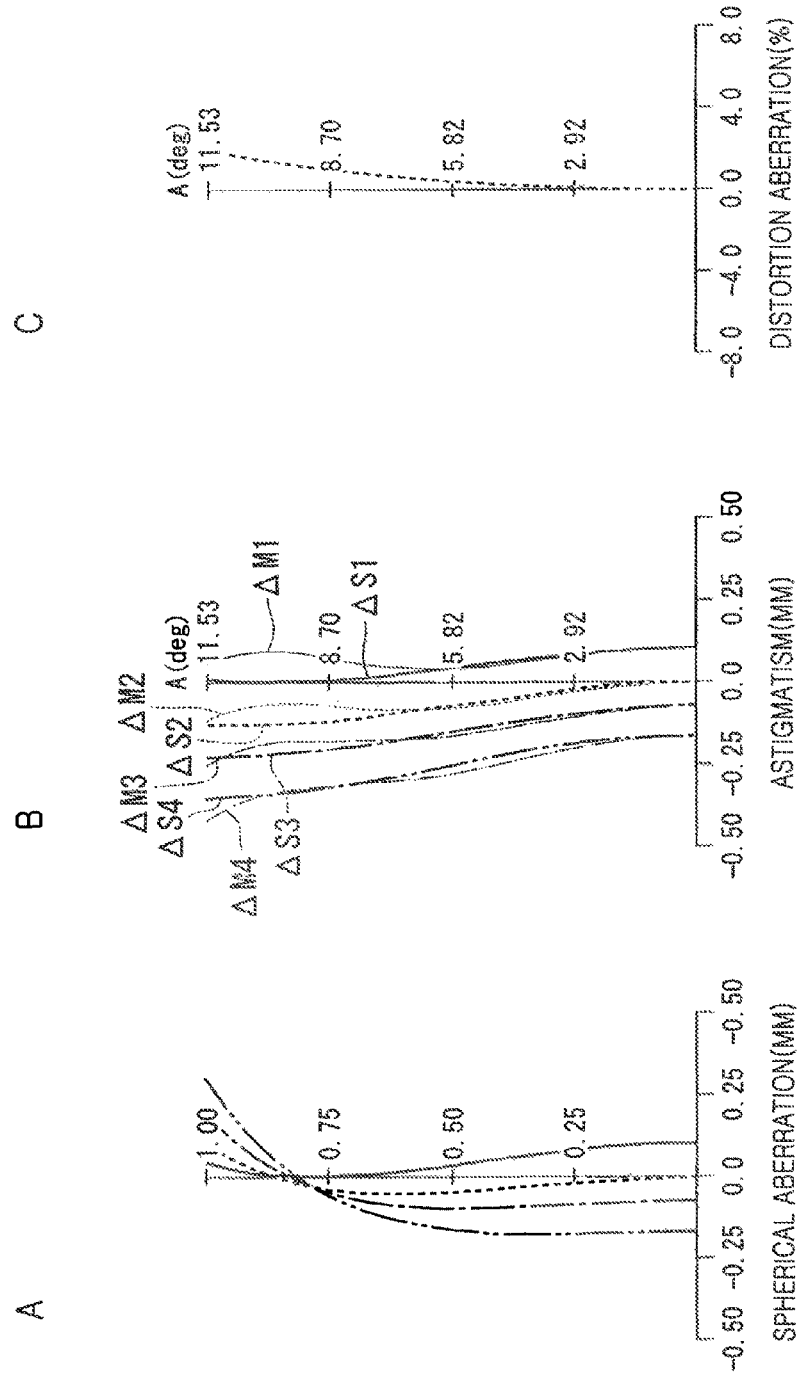

A
1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 -0.50
SPHERICAL ABERRATION(MM)
B
ΔM3
ΔS4
ΔM4
ΔM2
ΔS2
ΔS3
ΔM1
ΔS1
A(deg)
11.53
8.70
5.82
2.92
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
C
A(deg)
11.53
8.70
5.82
2.92
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 27

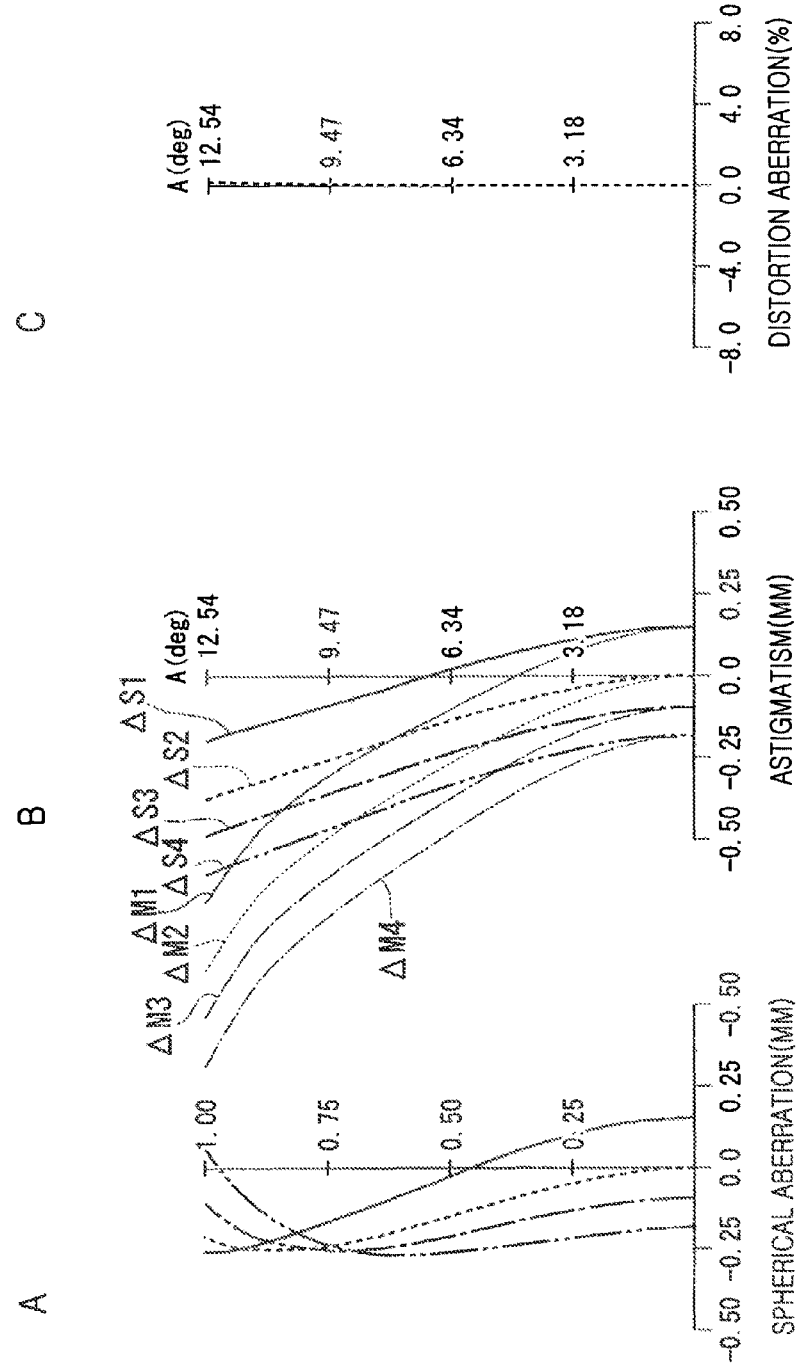

A
B
C
SPHERICAL ABERRATION(MM)
1.00
0.75
0.50
0.25
0.0
-0.25
-0.50
ΔM1
ΔM2
ΔM3
ΔM4
ΔS1
ΔS2
ΔS3
ΔS4
ASTIGMATISM(MM)
A(deg)
12.54
9.47
6.34
3.18
DISTORTION ABERRATION(%)
8.0
4.0
0.0
-4.0
-8.0

FIG. 28

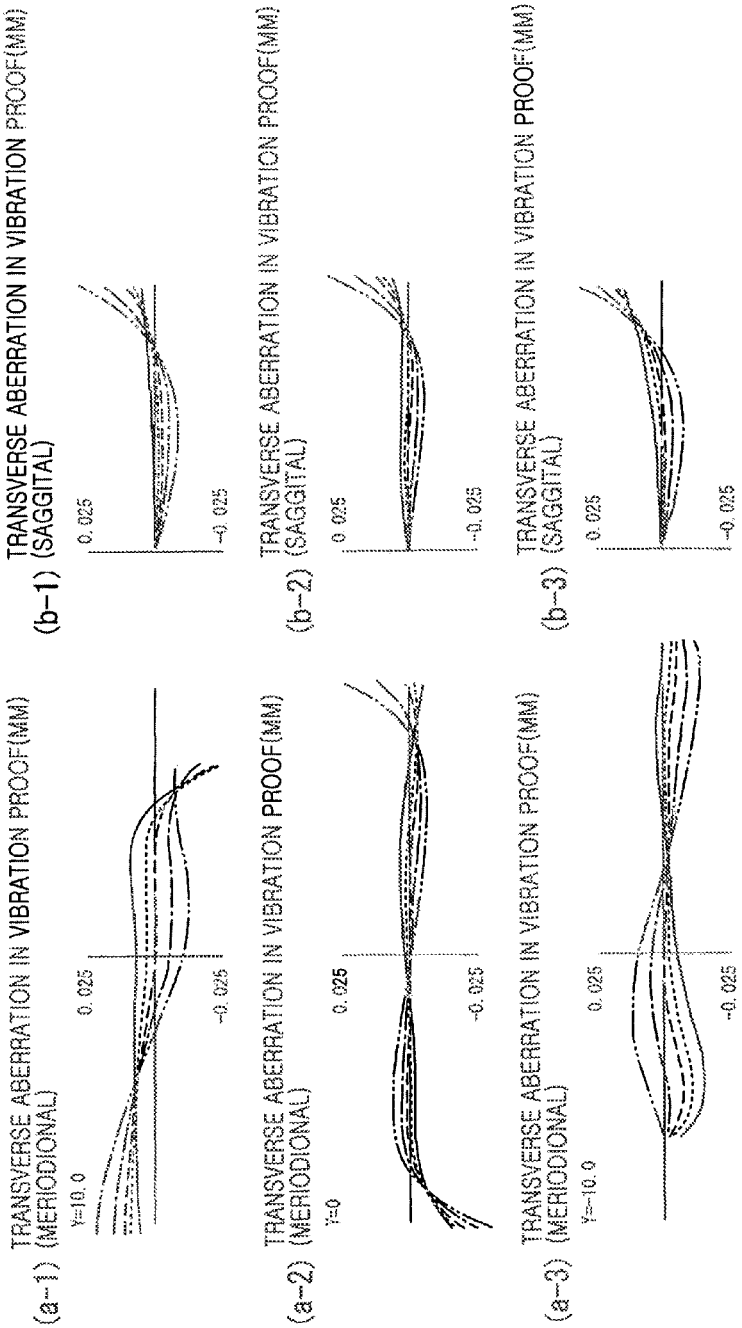

(a-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=10.0
0.025
-0.025
(a-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=0
0.025
-0.025
(a-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=-10.0
0.025
-0.025
(b-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(b-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(b-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025

FIG. 29

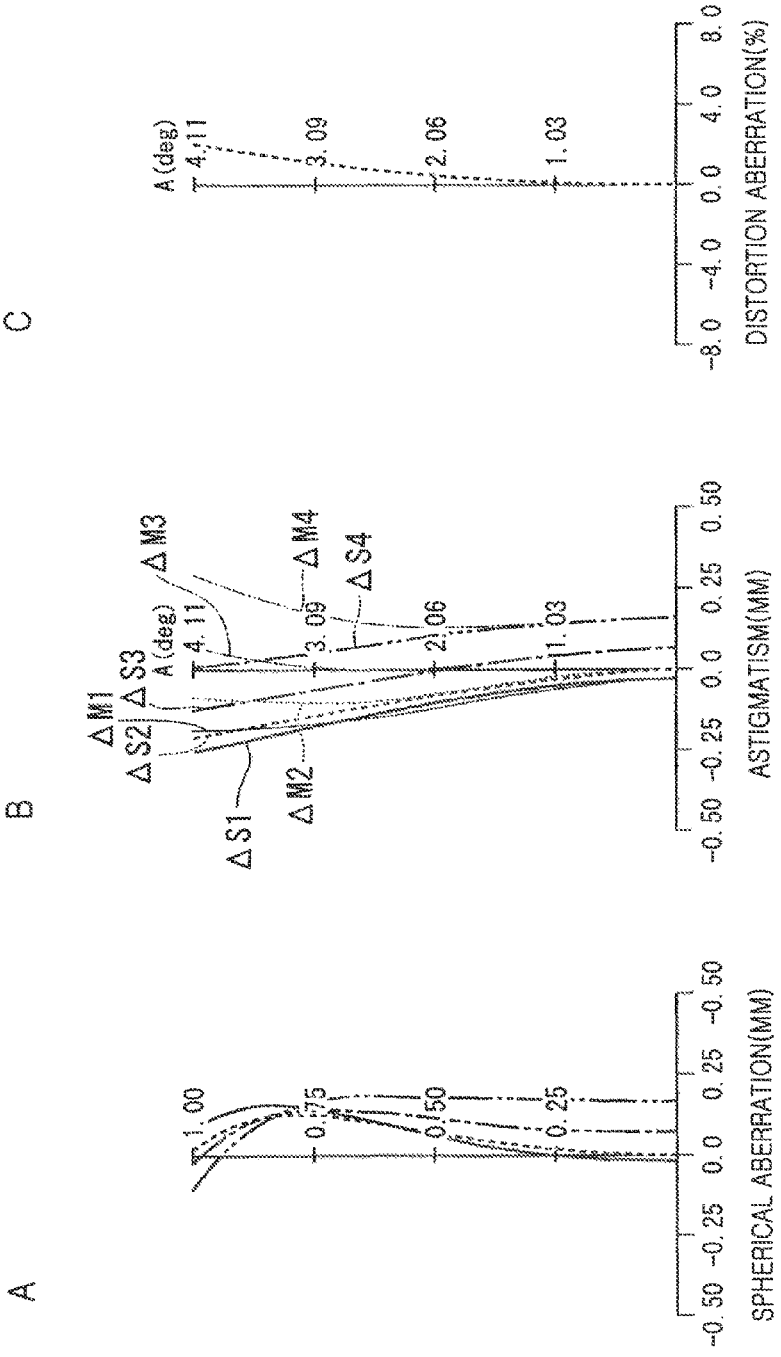

A
B
C
ω 1.00
0.75
0.50
0.25
-0.50 -0.25 0.0 0.25 0.50
SPHERICAL ABERRATION(MM)
ΔM1
ΔS2
ΔS3
ΔM3
A (deg)
4.11
3.09
2.06
1.03
ΔS1
ΔM2
ΔM4
ΔS4
-0.50 -0.25 0.0 0.25 0.50
ASTIGMATISM(MM)
A (deg)
4.11
3.09
2.06
1.03
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 30

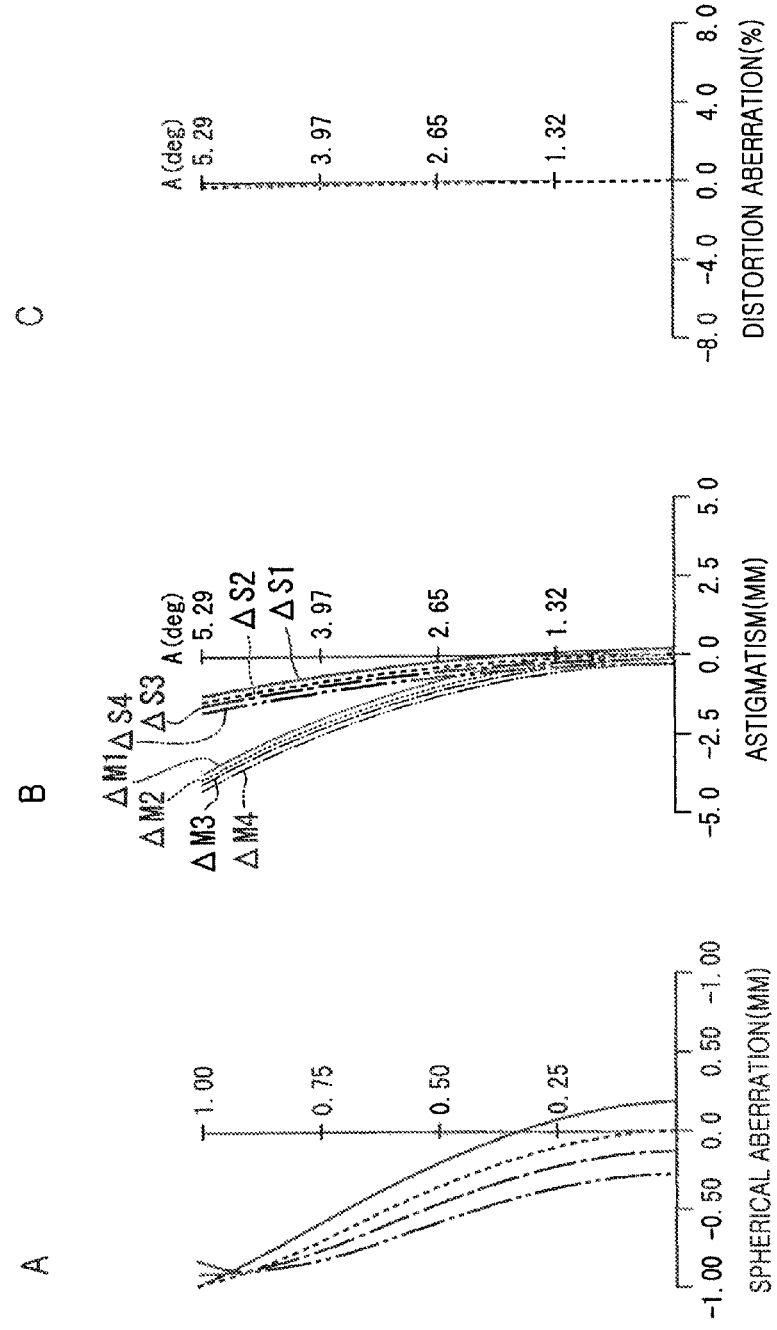
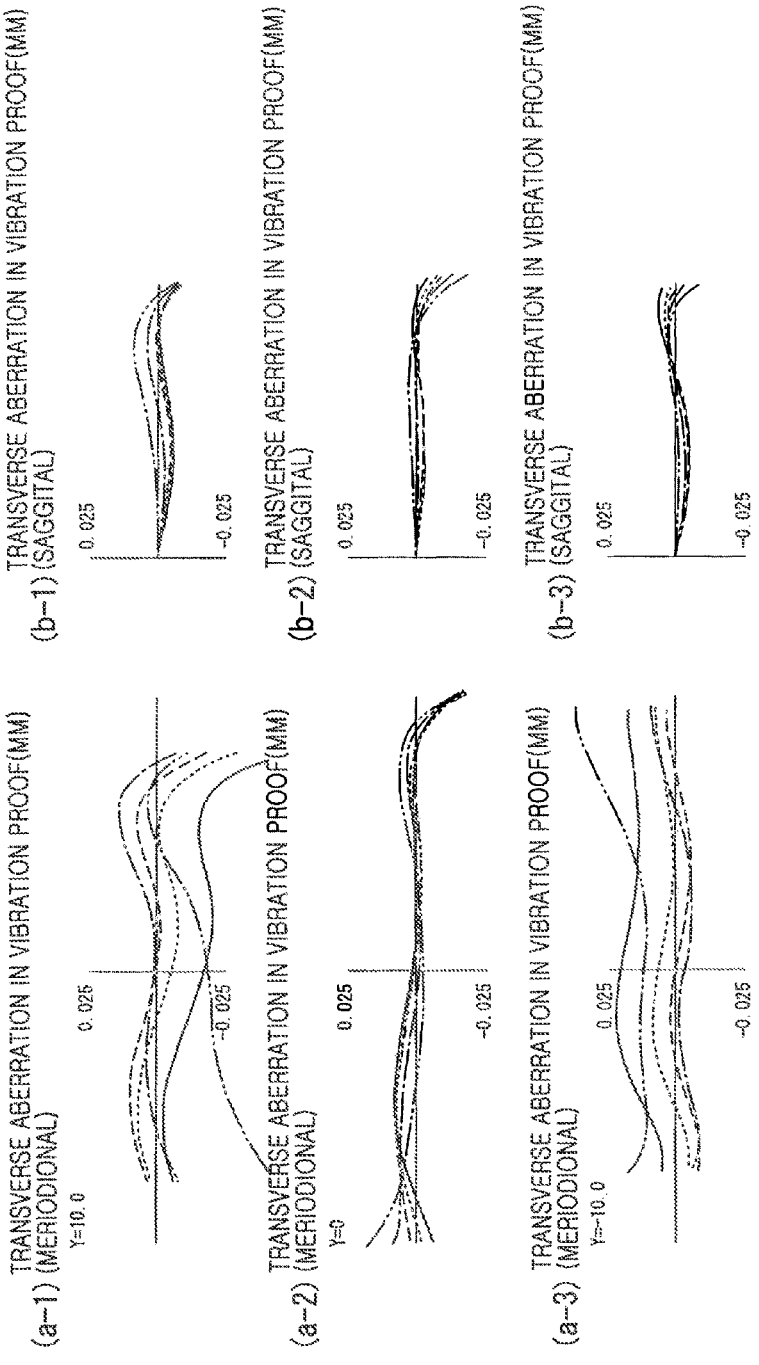

A
B
C
1.00
0.75
0.50
0.25
-1.00 -0.50 0.0 0.50 -1.00
SPHERICAL ABERRATION(MM)
ΔM1 ΔS4
ΔM2
ΔM3
ΔM4
ΔS3
ΔS2
ΔS1
A(deg)
5.29
3.97
2.65
1.32
-5.0 -2.5 0.0 2.5 5.0
ASTIGMATISM(MM)
A(deg)
5.29
3.97
2.65
1.32
-8.0 -4.0 0.0 4.0 8.0
DISTORTION ABERRATION(%)

FIG. 31


(a-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=10.0
0.025
-0.025
(a-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=0
0.025
-0.025
(a-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(MERIODIONAL)
Y=-10.0
0.025
-0.025
(b-1) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(b-2) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025
(b-3) TRANSVERSE ABERRATION IN VIBRATION PROOF(MM)
(SAGGITAL)
0.025
-0.025

VIBRATION PROOF ZOOM LENS AND PHOTOGRAPHING APPARATUS HAVING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from Japanese Patent Application No. 2010-284858, filed Dec. 21, 2010, in the Japan Intellectual Property Office, and Korean Patent Application No. 2011-0123237, filed on Nov. 23, 2011, in the Korean Intellectual Property Office, the disclosures of which are incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Inventive Concept

Apparatuses and methods consistent with the present inventive concept relate to a vibration proof zoom lens and a photographing apparatus having the same.

2. Description of the Related Art

There have been proposed various zoom lenses with a device (vibration-proofing apparatus) compensating for image shaking caused by vibrations fortuitously transmitted to a photographing system. For instance, there is known a zoom lens (vibration proof zoom lens), in which to compensate for the image shaking caused by the vibrations, moves a portion of lens groups forming the zoom lens in a vertical direction to an optical axis.

Examples of such a zoom lens are disclosed in, for example, Japanese Patent Laid-open Nos. 2006-106191 and 2009-284763. The disclosed zoom lenses (vibration proof zoom lenses), which have a vibration proof function, are composed of a first lens group with a positive refractive power, a second lens group with a negative refractive power, a third lens group with a positive refractive power, and a fourth lens group with a positive refractive power, which are arranged in order from an object side, respectively. The third lens group consists of a front group with a positive refractive power and a rear group with a negative refractive power, and the rear group is moved in the vertical direction to the optical axis to compensate for the image shaking.

In the zoom lenses disclosed in Japanese patent laid-open Nos. 2006-106191 and 2009-284763, a focusing operation from a far distance to a close distance is performed by moving the second lens group toward the object side.

On the other hand, there are known various methods of focusing the zoom lens to the close distance. For instance, there is known an optical system in which a most front lens can be restrained in diameter and which as a zoom lens desirable for high variable-magnifying or zooming, has a first lens group with a positive refractive power, a second lens group with a negative refractive power and a third lens group with a positive lens refractive power arranged in order from the object side (see, for example, Japanese Patent Laid-open Nos. H10-133109 and H10-133111). In the optical system, the focusing is performed at the third lens group.

In the conventional vibration proof zoom lenses as described above, however, problems have been discovered, as follows:

The zoom lenses disclosed in Japanese patent laid-open Nos. 2006-106191 and 2009-284763 perform the focusing by moving the second lens group. In the zoom lenses, however, since the second lens group with the negative refractive power preceding the first lens group with the positive refractive power generally contributes to a major variable magnification among the entire optical system, it has a relatively large number of lenses, and is large even in mass. For instance, the second lens group disclosed in the Japanese patent laid-open Nos. 2006-106191 and 2009-284763 is composed of four lenses, which include a negative meniscus lens having a convex surface toward the object side, a bi-concave lens, a bi-convex lens and a negative meniscus lens having a concave surface toward the object side.

On this account, there are problems in that it is difficult to control the second lens group to move forward and rearward in very small amounts and is not adapted to, particularly, a so-called contrast detection type auto focus by a blur detection of an image pickup device.

Also, the zoom lenses disclosed in Japanese Patent Laid-open Nos. H10-133109 and H10-133111 perform the focusing at the third lens group with a positive refractive power. In the zoom lenses, however, since the third lens group is composed of three cemented lens, each of in which a positive lens, a positive lens and a negative lens are cemented with one another, there are problems in that this third lens group also has a relatively large number of lenses and is not adapted to, particularly, the so-called contrast detection type auto focus.

On this account, there is a need for a vibration proof zoom lens, which establishes a sufficient close distance while having a high variable-magnification and a good optical performance, and which is adapted to, particularly, the contrast detection type auto-focus by the blur detection of the image pickup device.

SUMMARY

Additional features and utilities of the present general inventive concept will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the general inventive concept.

The present inventive concept provides a vibration proof zoom lens system, which establishes a sufficient close distance while having a high variable-magnification and a good optical performance, and which is adapted to a so-called contrast detection type auto-focus by a blur detection of an image pickup device, and a photographing apparatus having the same.

Exemplary embodiments of the present general inventive concept provide a vibration proof zoom lens system which includes a first lens group with a positive refractive power, a second lens group with a negative refractive power, and a succeeding group having a positive refractive power as a whole, which are arranged in order from an object side of the system, wherein the succeeding group has a first part group with a positive refractive power, a second part group with a positive refractive power including more than one cemented lens to form at least two cemented surfaces, and a third part group with a negative refractive power, which are arranged in order from the object side, wherein in variable-magnifying from a wide angle limit to a telephoto limit, a clearance between the first lens group and the second lens group is increased and at the same time, a clearance between the second lens group and the succeeding group is decreased, wherein a focusing from an infinity side to a close side is performed by moving the first part group toward an image side of the system, wherein a vibration proof operation is performed by moving the third part group in a direction

perpendicular to an optical axis to change an image position, and wherein the following condition equations (1), (2) and (3) are satisfied:

$$0.1<f_{3a}/f_t<0.3 \quad (1)$$

$$0.15<f_{3b}/f_t<0.35 \quad (2)$$

$$0.05<|f_{3c}|/f_t<0.25 \quad (3)$$

Here, f_{3a} is a focal length of the first part group, f_{3b} is a focal length of the second part group, f_{3c} is a focal length of the third part group, and f_t is a focal length of all systems at the telephoto limit.

In an exemplary embodiment, the succeeding group may be provided with a first part group, the second part group and a third part group, which are arranged in order from the object side to have the positive refractive power, the positive refractive power and the negative refractive power, respectively. Like this, since in addition to the first part group carrying out the focusing from the infinity side to the close side and the third part group with the negative refractive power carrying out the vibration proof, there is provided the second part group with the positive refractive power, a degree of freedom in refractive power setting is improved, as compared with a case that a positive refractive power required at the succeeding group is established only by the first part group and the third part group, and it becomes easy to restrain a change in aberration according to the focusing or a change in aberration during the vibration proof.

Further, it is possible to simplify a configuration of the first part group.

Furthermore, as the second part group is arranged between the first part group and the third part group, a degree of freedom in transverse magnification setting with the first part group and the third part group is enlarged, thereby allowing a sensitivity of focusing of the first part group and a sensitivity of the vibration proof operation of the second part group (an amount of image movement per a displacement amount to a direction perpendicular to an optical axis of the third part group) to easily control.

Moreover, as the second part group includes more than one cemented lens to have a configuration in which at least two cemented surfaces are formed, it becomes easy to restrain even a change in chromatic aberration during the vibration proof because it can better correct a chromatic aberration of object side optical system than the third part group.

Also, since the third lens group satisfies the condition equations (1), (2) and (3), it becomes easy to correct the aberration even in the high variable-magnification and a good optical performance can be obtained.

Exemplary embodiments of the present general inventive concept also provide a photographing apparatus which is configured to have the vibration proof zoom lens system as described above.

According to the photographing apparatus, it includes the same function or operation as the vibration proof zoom lens system according to an aspect of the present inventive concept described above because it has the vibration proof zoom lens system described above.

With the vibration proof zoom lens system and the photographing apparatus having the same according to the descriptions above, the succeeding group is provided with the first part group, the second part group and the third part group, which are arranged in order from the object side to have the positive refractive power, the positive refractive power and the negative refractive power, respectively. Thus, with the second part group, the degree of freedom in refractive power setting is improved and a color compensation becomes much easier. Also, the first part group can be simplified. Accordingly, the effect, which establishes the sufficient close distance while having the high variable-magnification and the good optical performance, and which is adapted to the so-called contrast detection type auto-focus by the blur detection of the image pickup device, can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and/or other features of the present inventive concept will become more apparent by describing certain exemplary embodiments of the present inventive concept with reference to the accompanying drawings, in which:

FIGS. **1**A-**1**C are cross-sectional views showing vibration proof zoom lenses according to an exemplary embodiment when it focuses on an infinity object point at a wide angle limit, an intermediate focal length, and a telephoto limit, respectively;

FIG. **2** is a mimetic diagram showing a construction of integral parts of a photographing apparatus having the vibration proof zoom lens according to the exemplary embodiment of FIG. **1**;

FIGS. **3**A-**3**C are cross-sectional views showing vibration proof zoom lenses according to another exemplary embodiment when it focuses on the infinity object point at the wide angle limit, the intermediate focal length, and the telephoto limit, respectively;

FIGS. **4**A-**4**C is cross-sectional views showing vibration proof zoom lenses according to yet another exemplary embodiment when it focuses on the infinity object point at the wide angle limit, the intermediate focal length, and the telephoto limit, respectively;

FIGS. **5**A-**5**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment illustrated in FIG. **1** when it focuses on an infinity object distance at the wide angle limit, respectively;

FIGS. **6**A-**6**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **1** when it focuses on an object distance of 0.5 m at the wide angle limit, respectively;

FIG. **7** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIG. **1** when it vibration-proofs at the wide angle limit;

FIGS. **8**A-**8**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **1** when it focuses on the infinity object distance at the intermediate focal length, respectively;

FIGS. **9**A-**9**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **1** when it focuses on the object distance of 0.5 m at the intermediate focal length, respectively;

FIG. **10** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIG. **1** when it vibration-proofs at the intermediate focal length;

FIGS. **11**A-**11**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **1** when it focuses on the infinity object distance at the telephoto limit, respectively;

FIGS. **12**A-**12**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary

embodiment of FIG. **1** when it is in focus to the object distance of 0.5 m at the telephoto limit, respectively;

FIG. **13** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIG. **1** when it vibration-proofs at the telephoto limit;

FIGS. **14**A-**14**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **3** when it focuses on the infinity object distance at the wide angle limit, respectively;

FIGS. **15**A-**15**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **3** when it focuses on the object distance of 0.5 m at the wide angle limit, respectively;

FIG. **16** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIG. **3** when it vibration-proofs at the wide angle limit;

FIGS. **17**A-**17**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **3** when it focuses on the infinity object distance at the intermediate focal length, respectively;

FIGS. **18**A-**18**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **3** when it focuses on the object distance of 0.5 m at the intermediate focal length, respectively;

FIG. **19** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIG. **3** when it vibration-proofs at the intermediate focal length;

FIGS. **20**A-**20**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIG. **3** when it focuses on the infinity object distance at the telephoto limit, respectively;

FIGS. **21**A-**21**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIGS. **3**A-**3**C when it focuses on the object distance of 0.5 m at the telephoto limit, respectively;

FIG. **22** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIGS. **3**A-**3**C when it vibration-proofs at the telephoto limit;

FIGS. **23**A-**23**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIGS. **4**A-**4**C when it focuses on the infinity object distance at the wide angle limit, respectively;

FIGS. **24**A-**24**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIGS. **4**A-**4**C when it is in focus to the object distance at 0.5 m at the wide angle limit, respectively;

FIG. **25** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIG. **4**A-**4**C when it vibration-proofs at the wide angle limit;

FIGS. **26**A-**26**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIGS. **4**A-**4**C when it focuses on the infinity object distance at the intermediate focal length, respectively;

FIGS. **27**A-**27**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIGS. **4**A-**4**C when it focuses on the object distance of 0.5 m at the intermediate focal length, respectively;

FIG. **28** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIGS. **4**A-**4**C when it vibration-proofs at the intermediate focal length;

FIGS. **29**A-**29**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIGS. **4**A-**4**C when it focuses on the infinity object distance at the telephoto limit, respectively;

FIGS. **30**A-**30**C are aberration views showing a spherical aberration, an astigmatism, and a distortion aberration of the vibration proof zoom lens according to the exemplary embodiment of FIGS. **4**A-**4**C when it focuses on the object distance of 0.5 m at the telephoto limit, respectively; and

FIG. **31** is an aberration view showing a transverse aberration according to the exemplary embodiment of FIGS. **4**A-**4**C when it vibration-proofs at the telephoto limit.

DETAILED DESCRIPTION

Exemplary embodiments of the present inventive concept are described in greater detail below with reference to the accompanying drawings. Throughout the drawings, the same reference numerals will be understood to refer to the same or corresponding elements, features, and structures, even in different embodiments. Also, for the sake of convenient explanation, descriptions on overlapped functions or constructions will be omitted.

A vibration proof zoom lens according to an exemplary embodiment of the present inventive concept will be explained below.

Accordingly to an exemplary embodiment, FIGS. **1**A-**1**C are cross-sectional views showing vibration proof zoom lenses when focusing on an infinity object point at a wide angle limit, an intermediate focal length, and a telephoto limit, respectively. In these drawings, a reference mark O designates an optical axis of the vibration proof zoom lens, and a reference mark IP designates an image surface (the same in below drawings). FIG. **2** is a mimetic diagram showing a construction of integral parts of a photographing apparatus having the vibration proof zoom lens according to the exemplary embodiment of FIGS. **1**A-**1**C.

In addition, in FIGS. **1**A-**1**C, to allow for better seeing, reference marks designating an aspherical surface and a cemented surface are included only in FIG. **1**B.

As shown in FIG. **1**A, the vibration proof zoom lens system **100** according to the present exemplary embodiment is a zoom optical system, which a first lens group G**1**, a second lens group G**2**, a third lens group G**3**, a fourth lens group G**4**, and an optical filter (LPF) made of a parallel plate are arranged in order from an object side of the lens system (hereinafter referred to as "object side").

An aperture S, which is moved with the third lens group G**3** in a body, is provided between the second lens group G**2** and the third lens group G**3**.

Each of the first lens group G**1**, the second lens group G**2**, the aperture S, the third lens group G**3** except a third part group to be described later, and the fourth lens group G**4** is disposed at a position coaxial with the optical axis O. The third part group to be described later is disposed at the position coaxial with the optical axis O except during a vibration proof operation.

The first lens group G**1** in which a cemented lens **1** and a positive lens **2** made of a positive meniscus lens having a convex surface toward the object side are disposed in order

from the object side is configured, so that the first lens group G1 has a positive refractive power as a whole.

The cemented lens **1** in which a negative lens **1**A made of a negative meniscus lens having a convex surface toward the object side and a positive lens **1**B made of a bi-convex lens are arranged and cemented in order from the object side has a positive refractive power as a whole. Between the negative lens **1**A and the positive lens **1**B is formed a cemented surface **1***a* (see FIG. **1**B).

The second lens group G**2** in which a negative lens **3** made of a negative meniscus lens having a convex surface toward the object side, a negative lens **4** made of a bi-concave lens, a positive lens **5** made of a bi-convex lens and a negative lens **6** made of a bi-concave lens are arranged in order from the object side is configured, so that the second lens group G**2** has a negative refractive power as a whole.

Further, assuming that a focal length of all systems at a telephoto limit of the vibration proof zoom lens system **100** (here, a focal length at a wavelength of 546.1 nm and the same even in a focal length thereblow) is f_t, a focal length of the first lens group G**1** is f_1 and a focal length of the second lens group G**2** is f_2, the first and the second lens groups G**1** and G**2** according to the present exemplary embodiment preferably satisfy the following condition equations (6) and (7):

$$0.25<f_1/f_t<0.65 \quad (6)$$

$$0.04<|f_2|/f_t<0.1 \quad (7)$$

The condition equation (6) is a desirable condition on the focal length of the first lens group G**1**. If f_1/f_t is less than the upper limit of 0.65, it is preferable because it becomes easier to make the entire length of optical system smaller, and if larger than the lower limit of 0.25, it is preferable because it becomes easier to correct a spherical aberration at the telephoto limit.

The condition equation (7) is a desirable condition on the focal length of the second lens group G**2**. If $|f_2|/f_t$ is less than the upper limit of 0.1, it is preferable because it becomes easier to establish a variable-magnifying rate, and if larger than the lower limit of 0.04, it is preferable because it becomes easier to correct a distortion aberration at the wide angle limit.

It is desirable that values of f_1/f_t and $|f_2|/f_t$ are within a range as narrow as possible in the condition equations (6) and (7). For instance, f_1/f_1 is preferable within a range as defined by the following condition equation (6a), and $|f_2|/f_t$ is preferable within a range as defined by the following condition equation (7a).

$$0.35<f_1/f_t<0.55 \quad (6a)$$

$$0.055<|f_2|/f_t<0.085 \quad (7a)$$

The third lens group G**3** in which a first part group with a positive refractive power, a second part group with a positive refractive power and a third part group with a negative refractive power are arranged in order from the object side has a positive refractive power as a whole.

The first, the second and the third part groups of the present exemplary embodiment comprise a positive lens **7**, a cemented lens **8**, and a cemented lens **9**, respectively.

The positive lens **7** is movably supported in a direction according to the optical axis O in the third lens group G**3**, and carries out a focusing from an infinity side of the system **100** to a close side of the system **100** by moving toward an image side (see an arrow Fin FIG. **1**A).

The positive lens **7** of the present exemplary embodiment comprises a bi-convex lens and has an image side lens surface consisting of an aspherical surface **7***a* (see FIG. **1**B) having a positive refractive power becoming smaller while moving away from an optical axis of the lens.

With the aspherical surface **7***a* configured as described above, it becomes easier to form the first part group in the form of one lens. In addition, as the aspherical surface **7***a* is configured to have the positive refractive power becoming smaller while moving away from the optical axis of lens, it becomes easier to restrain a change in spherical aberration according to the focusing, particularly, at the telephoto limit.

The cemented lens **8** of the present exemplary embodiment, in which a positive lens **8**A made of a bi-convex lens, a negative lens **8**B made of a negative concave lens and a positive lens **8**C made of a biconvex lens are arranged and cemented in order from the object side, has a positive refractive power as a whole. Between the positive lens **8**A and the negative lens **8**B is formed a cemented surface **8***a* (see FIG. **1**B) and between the negative lens **8**B and the positive lens **8**C is formed a cemented surface **8***b* (see FIG. **1**B).

According to the above described setup of lens **8**, the second part group of the present exemplary embodiment has a configuration having the cemented lens comprising two positive lenses **8**A and **8**C and one negative lens **8**B.

The cemented lens **9** is supported to be movable along a direction perpendicular to the optical axis O within the third lens group G**3**, and performs a vibration proof operation by moving in the direction perpendicular to the optical axis O to change an image position (see an arrow c in FIG. **1**A).

Here, the cemented lens **9** which moves in the direction perpendicular to the optical axis O, which means obtaining an eccentric amount in shift required in moving the image position to vibrate-proof the system, only needs to have a movement component in the direction perpendicular to the optical axis O by which the eccentric amount in shift is established. Accordingly, for instance, even if the movement deviates from the direction exactly perpendicular to the optical axis O due to tolerances in manufacturing or assembling parts, it should be appreciated to be within a scope of the inventive concept.

The cemented lens **9** of the present exemplary embodiment comprises a cemented lens in which a negative lens **9**A made of a bi-concave lens having an object side concave surface consisting of an aspherical surface **9***a* (see FIG. **1**B) and a positive lens **9**B made of a positive meniscus lens having a convex surface toward the object side are arranged and cemented in order from the object side, and has a negative refractive power as a whole.

The aspherical surface **9***a* the present exemplary embodiment is configured to have a negative refractive power becoming smaller while moving away from an optical axis of lens. As the most object side lens surface is of such an aspherical surface, it becomes easier to correct a coma-aberration in the vibration proof.

Between the negative lens **9**A and the positive lens **9**B is formed a cemented surface **9***b* (see FIG. **1**B).

According to the above described setup of lens **9**, the third part group has a configuration having the cemented lens comprising one negative lens **9**A and one positive lens **9**B.

Further, assuming that a focal length of the first part group (the positive lens **7**) is f_{3a}, a focal length of the second part group (the cemented lens **8**) is f_{3b}, and a focal length of the third part group (the cemented lens **9**) is f_{3c}, the third lens group G**3** of the present exemplary embodiment satisfies the following condition equations (1), (2) and (3):

$$0.1<f_{3a}/f_t<0.3 \quad (1)$$

$$0.15<f_{3b}/f_t<0.35 \quad (2)$$

$$0.05<|f_{3c}|/f_t<0.25 \quad (3)$$

The condition equation (1) is a condition on the focal length of the first part group. If f_{3a}/f_t is larger than the upper limit of 0.3, an amount of focus movement of the first part group at the telephoto limit becomes too large, and if less than the lower limit of 0.1, it becomes difficult to restrain a change in spherical aberration according to the focusing at the telephoto limit.

The condition equation (2) is a condition on the focal length of the second part group. If f_{3b}/f_t is larger than the upper limit of 0.35, it becomes difficult to maintain a variable-magnifying rate, and if exceeds the lower limit of 0.15, it becomes difficult to correct a spherical aberration at the telephoto limit.

The condition equation (3) is a condition on the focal length of the third part group. If $|f_{3c}|/f_t$ is larger than the upper limit of 0.25, a displacement amount of the third part group in the vibration proof at the telephoto limit becomes too large, and if less than the lower limit of 0.05, it becomes difficult to correct a change in coma-aberration in the vibration proof at the telephoto limit.

It is desirable that values of f_{3a}/f_t, f_{3b}/f_t and $|f_{3c}|/f_t$ are within a range as narrow as possible in the condition equations (1), (2) and (3). For instance, f_{3a}/f_t is preferable within a range as defined by the following condition equation (1a), f_{3b}/f_t is preferable within a range as defined by the following condition equation (2a) and $|f_{3c}|/f_t$ is preferable within a range as defined by the following condition equation (3a).

$$0.14<f_{3a}/f_t<0.23 \quad (1a)$$

$$0.20<f_{3b}/f_t<0.30 \quad (2a)$$

$$0.10<|f_3|/f_t<0.20 \quad (3a)$$

The fourth lens group G**4** of FIG. **1** in which a positive lens **10** made of a bi-convex lens having an aspherical surface **10***a* toward the image, a cemented lens **11**, and a positive lens **12** made of a bi-convex lens are arranged in order from the object side has a positive refractive power as a whole.

The aspherical surface **10***a* is of an aspherical surface having a positive refractive power becoming smaller while moving away from an optical axis of the lens.

The cemented lens **11** in which a positive lens **11**A made of a bi-convex lens and a negative lens **11**B made of a negative concave lens are arranged and cemented in order from the object side has a negative refractive power as a whole. Between the positive lens **11**A and the negative lens **11**B is formed a cemented surface **11***a* (see FIG. **1**B).

In this case, the third lens group G**3** and the fourth lend group G**4** form a succeeding group to the first lens group G**1** and the second lens group G**2** in the vibration proof zoom lens **100**, and have a positive refractive power as a whole.

Assuming that a focal length of the third lens group G**3** at the telephoto limit is f_{Ra} and a focal length of the fourth lens group G**4** is f_{Rb}, the succeeding group of the first exemplary embodiment preferably satisfy the following condition equations (4) and (5):

$$0.05<f_{Ra}/f_t<0.3 \quad (4)$$

$$0.1<f_{Rb}/f_t<0.35 \quad (5)$$

The condition equation (4) is a desirable condition on a focal length of an object side lens group (front lens group) including the first part group, the second part group and the third part group among the succeeding group. If f_{Ra}/f_t is less than the upper limit of 0.3, it is preferable because it becomes easier to make the entire size of optical system smaller, and if larger than the lower limit of 0.05, it is preferable because it becomes easier to correct a spherical aberration, particularly, at the telephoto limit.

The condition equation (5) is a desirable condition on a focal length of a lens group further toward the image (rear lens group) than the front lens group. If f_{Rb}/f_t is less than the upper limit of 0.35, it is preferable because it becomes easier to establish the variable-magnifying rate, and if larger than the lower limit of 0.1, it is preferable because it becomes easier to correct the distortion aberration, particularly, at the wide angle limit.

It is desirable that values of f_{Ra}/f_t and f_{Rb}/f_t are within a range as narrow as possible in the condition equations (4) and (5). For instance, f_{Ra}/f_t is preferable within a range as defined by the following condition equation (4a), and f_{Rb}/f_t is preferable within a range as defined by the following condition equation (5a),

$$0.12<f_{Ra}/f_t<0.22 \quad (4a)$$

$$0.17<f_{Rb}/f_t<0.29 \quad (5a)$$

Next, an operation of the vibration proof zoom lens system **100** according to the present exemplary embodiment will be explained.

As shown in FIGS. **1**A-**1**C, the vibration proof zoom lens **100** is operated, so that when at the time of focusing on an infinity object point, variable-magnifying from the wide angle limit (see FIG. **1**A) to the telephoto limit (see FIG. **1**C) via the intermediate focal length (see FIG. **1**B), all of the first lens group G**1**, the second lens group G**2**, the aperture S, the third lens group G**3** and the fourth lens group G**4** moves along the optical axis O toward the object side.

At this time, a clearance between the first lens group G**1** and the second lens group G**2** is increased and a clearance between the second lens group G**2** and the succeeding group G**3** is decreased.

Further, in the third lens group G**3**, a clearance between the first part group (the positive lens **7**) and the second part group (the cemented lens **8**) is increased.

A focusing from an infinity side to a close side can be performed by moving the first part group (the positive lens **7**) of the third lens group G**3** along the optical axis O toward the image side (see arrow F).

Since in the variable-magnifying from the wide angle limit to the telephoto limit, a clearance between the first part group and the second part group is increased as described above, it becomes easy for the entire optical system to arrange a refractive power of retro focus at the wide angle, thereby facilitating the wide angle. In addition, at the telephoto limit, it becomes easy to establish a moving space when the first part group moves for focusing.

Also, when the vibration proof zoom lens **100** is vibrated by, for example, hand tremors and the like, the vibration proof feature can be performed by moving the third part group (the cemented lens **9**) of the third lend group G**3** in the direction perpendicular to the optical axis O to move the position of an image in a opposite direction to a direction in which image vibrations occur.

As described above, according to the vibration proof zoom lens **100** of the present exemplary embodiment, the first lens group G**1** with the positive refractive power, the second lens group G**2** with the negative refractive power and the succeeding group having the positive refractive power as a whole are arranged in order from the object side, and thus the focusing from the telephoto side to the close side and the vibration proof operation can be performed by the succeeding group.

The succeeding group is provided with the first part group, the second part group and the third part group disposed in order from the object side to have the positive refractive power, the positive refractive power and the negative refractive power, respectively. Since in addition to the first part group carrying out the focusing from the infinity side to the close side and the third part group with the negative refractive power carrying out the vibration proof, there is provided the second part group (the cemented lens **8**) with the positive refractive power, a degree of freedom in refractive power setting can be improved, as compared with a case that the positive refractive power required at the succeeding group is established only by the first part group and the third part group.

On this account, restraining the change in aberration according to the focusing or the change in aberration during the vibration proof performance and the optical performance can be improved.

Further, it is possible to simplify the configuration of the first part group. In the present exemplary embodiment, since the first part group comprises one positive lens **7**, the lens can be reduced in weight and at the same time, a lens body tube for focusing is also simplified.

Accordingly, the vibration proof zoom lens **100** can be adapted to the contrast detection type auto focus by the blur detection of the image pickup device, which requires controlling, particularly, very small forward and rearward movements.

Furthermore, as the second part group is disposed between the first part group and the third part group, a degree of freedom in transverse magnification setting with the first part group and the third part group is enlarged, thereby allowing a sensitivity of focusing of the first part group and a sensitivity of vibration proof of the third part group to easily control.

Moreover, as the second part group has the cemented lens **8** in which two cemented surfaces **8***a* and **8***b* are formed, it becomes easy to correct a change in chromatic aberration during the vibration proof performance because it can better correct a chromatic aberration of object side optical system than the third part group.

Also, since the third lens group satisfies the condition equations (1), (2) and (3), it becomes easy to correct the aberration even in the high variable-magnification and a good optical performance can be obtained.

According to the construction of the present exemplary embodiment, as illustrated in a first example to be described later, it is possible to form a zoom lens with a vibration proof function, which can be focused on, for example, a close object distance of 0.5 m from an infinity object distance, and which has a focal length of wide angle limit of 18.5 mm and a focal length of telephoto limit of 194.15 mm.

Next, an example of a photographing apparatus having the vibration proof zoom lens **100** will be explained.

The photographing apparatus **110** is, for example, an interchangeable lens camera in which an auto focus is performed in a contrast detection method by a blur detection of an image pickup device.

As shown in FIG. **2**, the photographing apparatus **110** has a zoom body tube **113** in which the vibration proof zoom lens **100** of the present exemplary embodiment is disposed to allow for the variable-magnification operation, the focusing operation and the vibration proof operation, and is detachably mounted to a main body of the apparatus, which is not shown in the drawing.

In the zoom body tube **113** is provided a focusing actuator **114**, which has the positive lens **7** to be movable in a direction of the optical axis O within the third lens group G**3** during the focusing operation, and a vibration proof actuator **115**, which has the cemented lens **9** to be relatively movable in a direction perpendicular to the optical axis O within the third lens group G**3** during the vibration proof performance, based on an sensing output of a vibration detection sensor, which is not shown in the drawing.

When the zoom body tube **113** is mounted to the main body of the apparatus, the focusing actuator **114** and the vibration proof actuator **115** are electrically connected with a control unit **116** in the main body of the apparatus.

In the main body of the apparatus is provided an image pickup device **111** made up of a charge coupled device (CCD), a complementary metal-oxide semiconductor (CMOS) device or the like, having an image pickup surface on a surface (IP) toward an image, an image processing unit **112** to signal-process an image signal from the image pickup device **111** and thus to perform an auto focus sensing by the contrast detection method, and the control unit **116** electrically connected with the image processing unit **112** and electrically connected with the focusing actuator **114** and the vibration proof actuator **115** when the zoom body tube **113** is mounted to the main body of the apparatus, to perform the auto focusing operation by the contrast detection method and the vibration proof operation.

According to the photographing apparatus **110** constructed as described above, it includes the same function or operation as the vibration proof zoom lens **100** because it has the vibration proof zoom lens **100**. In particular, as the photographing apparatus **110** can easily perform the auto focus by the contrast detection method with the vibration proof zoom lens **100**, it can be formed compactly.

A vibration proof zoom lens according to another exemplary embodiment will be described below.

In FIGS. **3**A-**3**C are cross-sectional views showing vibration proof zoom lenses according to another exemplary embodiment when focusing on an infinity object point at a wide angle limit, an intermediate focal length, and a telephoto limit, respectively.

In addition, in FIGS. **3**A-**3**C, to allow for better seeing, reference marks designating an aspherical surface and a cemented surface are included only in FIG. **3**B.

As shown in FIG. **3**A, the vibration proof zoom lens **101** according to the present exemplary embodiment is provided with a first lens group G**11**, a second lens group G**12**, and a fourth lens group G**14**, which have the same configurations as the first lens group G**1**, the second lens group G**2**, and the fourth lens group G**4** of the vibration proof zoom lens **100** of the previous exemplary embodiment, respectively.

Further, the vibration proof zoom lens **101** is provided with a third lens group G**13**, instead of the third lens group G**3** of the vibration proof zoom lens **100**.

In addition to a first part group, a second part group and a third part group, which have the same configurations as those of the third lens group G**3** of the previous exemplary embodiment, the third lens group G**13** further includes a negative lens **30** as a fourth part group having a negative refractive power, which is disposed between an aperture S on an object side of the first part group and the second lens group G**12**, and has a positive refractive power as a whole. The fourth part group is of a subsidiary part group to adjust an arrangement of refractive power in the third lens group G**13**.

The third lens group G**13** and the fourth lens group G**14** form a succeeding group, which has a positive refractive power as a whole, to the first lens group G**11** and the second lens group G**12**.

Hereinafter, the vibration proof zoom lens **101** will be explained with priority given to different points from the vibration proof zoom lens **100** of the previous exemplary embodiment.

The first lens group G**11** of the present exemplary embodiment is made up of a cemented lens **21** consisting of a negative lens **21**A and a positive lens **216**, and a positive lens **22**, which correspond to and have the same configuration as the cemented lens **1** made of the negative lens **1**A and the positive lens **1**B and the positive lens **2** of the first lens group G**1** of the first exemplary embodiment. The cemented lens **21** has a cemented surface **21***a* (see FIG. **33**), which corresponds to the cemented surface **1***a* of the cemented lens **1**.

The second lens group G**12** of the present exemplary embodiment is made up of a negative lens **23**, a negative lens **24**, a positive lens **25**, and a negative lens **26**, which correspond to and have the same configuration as the negative lens **3**, the negative lens **4**, the positive lens **5** and the negative lens **6** of the second lens group G**2** of the previous exemplary embodiment.

The negative lens **30** of the third lens group G**13** of the present exemplary embodiment comprises a negative meniscus lens having a concave surface toward an object side.

Assuming that a focal length of the fourth part group is f_{3f}, the negative lens **30** preferably satisfies the following condition equation (8):

$$0.5<|f_{3f}|/f_t<5.0 \tag{8}$$

The condition equation (8) is a desirable condition on the focal length of the fourth part group. If $|f_{3f}|/f_t$ is less than the upper limit of 5.0, it is preferable because it becomes easier to make a focus sensitivity at a telephoto limit larger and at the same time, to make an amount of focus movement of the positive lens **27** smaller and if larger than the lower limit of 0.5, it is preferable because it becomes easier to correct a coma aberration at a wide angle limit.

It is desirable that a value of $|f_{3f}|/f_t$ is within a range as narrow as possible in the condition equation (8). For instance, $|f_{3f}|/f_t$ is preferable within a range as defined by the following condition equation (8a):

$$1.0<|f_{3f}|/f_t<2.0 \tag{8a}$$

In addition, the third lens group G **13** of the present exemplary embodiment is made up of a positive lens **27** (first part group), a cemented lens **28** (second part group) consisting of a positive lens **28**A, a negative lens **28**B and a positive lens **28**C, and a cemented lens **29** (third part group) consisting of a negative lens **29**A and a positive lens **29**B, which correspond to and have the same configurations as the positive lens **7**, the cemented lens **8** consisting of the positive lens **8**A, the negative lens **8**B and the positive lens **8**C, and the cemented lens **9** consisting of the negative lens **9**A and the positive lens **9**B of the third lens group G**3** of the previous exemplary embodiment.

An image side lens surface of the positive lens **27** is composed of an aspherical surface **27***a* (see FIG. **3**B) having a positive refractive power becoming smaller while moving away from an optical axis of the lens, which corresponds to the aspherical surface **7***a* of the positive lens **7**.

The cemented lens **28** is provided with cemented surfaces **28***a* and **28***b* (see FIG. **3**B), which corresponds to the cemented surfaces **8***a* and **8***b* of the cemented lens **8**.

A most object side lens surface of the cemented lens **29** comprises an aspherical surface **29***a* (see FIG. **3**B) having a negative refractive power becoming smaller while moving away from the optical axis of lens, which corresponds to the aspherical surface **9***a* of the positive lens **9**. In addition, the cemented lens **29** is provided with a cemented surface **29***b* (see FIG. **3**B), which corresponds to the cemented surface **9***b* of the cemented lens **9** of FIG. **1**.

The fourth lens group G**14** of the present exemplary embodiment comprises a positive lens **31**, a cemented lens **32** consisting of a positive lens **32**A and a negative lens **32**B, and a positive lens **33**, which correspond to and have the same configurations as the positive lens **10**, the cemented lens **11** consisting of the positive lens **11**A and the negative lens **11**B, and the positive lens **12** of the fourth lens group G**4** of the previous exemplary embodiment.

An image side lens surface of the positive lens **31** comprises an aspherical surface **31***a* (see (b) Of FIG. **3**) having a positive refractive power becoming smaller while moving away from the optical axis of lens, which corresponds to the aspherical surface **10***a* of the positive lens **10**.

The cemented lens **32** is provided with a cemented surface **32***a* (see FIG. **3**B), which corresponds to the cemented surface **11***a* of the cemented lens **11**.

Further, like the first and the second lens groups G**1** and G**2** of the previous exemplary embodiment, the first and the second lens groups G**11** and G**12** of the present exemplary embodiment preferably satisfy the condition equations (6) and (7), more particularly, (6a) and (7a), as described above.

Furthermore, like the third lens groups G**3** of the previous exemplary embodiment, the third lens groups G**13** of the present exemplary embodiment satisfies the condition equations (1), (2) and (3) as described above.

In particular, the third lens groups G**13** preferably satisfies the condition equations (1a), (2a) and (3a) as described above.

Also, like the succeeding group of the previous exemplary embodiment, the succeeding group of the present exemplary embodiment preferably satisfies the condition equations (4) and (5), more particularly, (4a) and (5a), as described above.

Next, an operation of the vibration proof zoom lens **101** of the present exemplary embodiment will be explained.

As shown in FIGS. **3**A-**3**C, like the vibration proof zoom lens system **100** of the previous exemplary embodiment, the vibration proof zoom lens system **101** is operated, so that when at the time of focusing on an infinity object point, variable-magnifying from a wide angle limit (see FIG. **3**A) to a telephoto limit (see FIG. **3**C) via an intermediate focal length (see FIG. **3**B), all of the first lens group G**11**, the second lens group G**12**, the aperture S, the third lens group G**13** and the fourth lens group G**14** move along the optical axis O toward the object side. At this time, a clearance between the first lens group G**11** and the second lens group G**12** is increased and a clearance between the second lens group G**12** and the succeeding group G**13** is decreased.

Further, in the third lens group G**13**, a clearance between the first part group (the positive lens **27**) and the second part group (the cemented lens **28**) is increased. Also, a clearance between the fourth part group (the negative lens **30**) and the first part group is decreased.

Like the vibration proof zoom lens **100** of the previous exemplary embodiment, a focusing from an infinity side to a close side can be performed by moving the first part group (the positive lens **27**) of the third lens group G**13** along the optical axis O toward an image side.

Also, when the vibration proof zoom lens **101** is vibrated by, for example, hand tremors and the like, the vibration proof operation can be performed by moving the third part group (the cemented lens **29**) of the third lend group G**13** in a direction perpendicular to the optical axis O to move a position of the image in an opposite direction to a direction in which image vibrations occur.

As described above, since the vibration proof zoom lens system **101** has the same configuration as the vibration proof zoom lens **100** of the previous exemplary embodiment, it includes the same function or operation as the vibration proof zoom lens system **100**.

Further, according to the vibration proof zoom lens system **101**, since the succeeding group further includes the fourth part group (the negative lens **30**) with the negative refractive power toward the image side of the first part group, a degree of freedom in refractive power setting of the third lens group G**13** is more increased. Thus, it becomes easier to control a focusing sensitivity of the first part group and a vibration proof sensitivity of the third part group. On this account, it is possible to improve a correction of a change in aberration according to the focusing operation or a change in aberration during the vibration proof operation, and an optical performance can also be improved.

Also, since the vibration proof zoom lens system **101** is adapted to the contrast detection type auto focus, it is possible for the photographing apparatus **110** of FIG. **2** to employ this vibration proof zoom lens system **101** as an alternative to the vibration proof zoom lens system **100**.

A vibration proof zoom lens system according to yet another exemplary embodiment will be described below.

FIGS. **4**A-**4**C are cross-sectional views showing vibration proof zoom lenses according to yet another exemplary embodiment when focusing on an infinity object point at a wide angle limit, an intermediate focal length, and a telephoto limit, respectively.

In addition, in FIGS. **4**A-**4**C, to allow for better view of FIGS. **4**A-**4**C, reference marks designating an aspherical surface and a cemented surface are included only in FIG. **4**B.

As shown in FIG. **4**A, the vibration proof zoom lens system **102** according to the present exemplary embodiment is provided with a first lens group G**21**, a second lens group G**22**, and a fourth lens group G**24**, which have the same configurations as the first lens group G**11**, the second lens group G**12**, and the fourth lens group G**14** of the vibration proof zoom lens **101** of the previous exemplary embodiment, respectively.

Further, instead of the third lens group G**13** of the vibration proof zoom lens **101**, the vibration proof zoom lens **102** is provided with a third lens group G**23** in which first to third part groups except a fourth part group have the same configurations as those of the third lens group G**13**.

Hereinafter, the vibration proof zoom lens **102** will be explained with priority given to different points from the vibration proof zoom lens **101** of the previous exemplary embodiment.

The first lens group G**21** of the present exemplary embodiment comprises a cemented lens **41** including a negative lens **41**A and a positive lens **41**B, and a positive lens **42**, which correspond to and have the same configuration as the cemented lens **21** consisting of the negative lens **21**A and the positive lens **21**B and the positive lens **22** of the first lens group G**12** of the previous exemplary embodiment. The cemented lens **41** has a cemented surface **41***a* (see FIG. **46**), which corresponds the cemented surface **21***a* of the cemented lens **21**.

The second lens group G**22** of the present exemplary embodiment is made up of a negative lens **43**, a negative lens **44**, a positive lens **45**, and a negative lens **46**, which correspond to and have the same configuration as the negative lens **23**, the negative lens **24**, the positive lens **25** and the negative lens **26** of the second lens group G**12** of the previous exemplary embodiment.

The third lens group G**23** of the present exemplary embodiment is provided with a negative lens **50** consisting of a negative meniscus lens having a convex surface toward an object side, instead of the negative lens **30** of the previous exemplary embodiment, as a fourth part group with a negative refractive power.

The negative lens **50** preferably satisfies the condition equation (8), more particularly, (8a), as described above.

Also, the third lens group G**23** of the present exemplary embodiment includes a positive lens **47** (first part group), a cemented lens **48** (second part group) consisting of a positive lens **48**A, a negative lens **48**B and a positive lens **48**C, and a cemented lens **49** (third part group) consisting of a negative lens **49**A and a positive lens **49**B, which correspond to and have the same configurations as the positive lens **27**, the cemented lens **28** consisting of the positive lens **28**A, the negative lens **28**B and the positive lens **28**C, and the cemented lens **29** consisting of the negative lens **29**A and the positive lens **29**B of the third lens group G**13** of the previous exemplary embodiment.

An image side lens surface of the positive lens **47** comprises an aspherical surface **47***a* (see FIG. **4**B) having a positive refractive power becoming smaller while moving away from an optical axis of the lens, which corresponds to the aspherical surface **27***a* of the positive lens **27**. In addition, the cemented lens **49** is provided with a cemented surface **49***b* (see FIG. **4**B), which corresponds to the cemented surface **9***b* of the cemented lens **9**.

The cemented lens **48** is provided with cemented surfaces **48***a* and **48***b* (see FIG. **4**B), which corresponds to the cemented surfaces **28***a* and **28***b* of the cemented lens **28**.

A most object side lens surface of the cemented lens **49** comprises an aspherical surface **49***a* (see FIG. **4**B) having a negative refractive power becoming smaller while moving away from the optical axis of the lens, which corresponds to the aspherical surface **29***a* of the positive lens **29**.

The fourth lens group G**24** of the present exemplary embodiment comprises a positive lens **51**, a cemented lens **52** consisting of a positive lens **52**A and a negative lens **52**B, and a positive lens **53**, which correspond to and have the same configurations as the positive lens **31**, the cemented lens **32** consisting of the positive lens **32**A and the negative lens **32**B, and the positive lens **33** of the fourth lens group G**14** of the previous exemplary embodiment.

An image side lens surface of the positive lens **51** comprises an aspherical surface **51***a* (see FIG. **4**B) having a positive refractive power becoming smaller while moving away from the optical axis of lens, which corresponds to the aspherical surface **31***a* of the positive lens **31**.

The cemented lens **52** is provided with a cemented surface **52***a* (see FIG. **4**B), which corresponds to the cemented surface **32***a* of the cemented lens **32**.

Further, like the first and the second lens groups G**11** and G**12** of the previous exemplary embodiment, the first and the second lens groups G**21** and G**22** of the present exemplary embodiment preferably satisfy the condition equations (6) and (7), more particularly, (6a) and (7a), as described above.

Furthermore, like the third lens groups G**13** of the previous exemplary embodiment, the third lens groups G**23** of the present exemplary embodiment satisfies the condition equations (1), (2) and (3) as described above.

In particular, the third lens groups G**23** preferably satisfies the condition equations (1a), (2a) and (3a) as described above.

Also, like the succeeding group of the previous exemplary embodiment, the succeeding group of the present exemplary embodiment preferably satisfies the condition equations (4) and (5), more particularly, (4a) and (5a), as described above.

Next, an operation of the vibration proof zoom lens **102** of the present exemplary embodiment will be explained.

With the configuration as described above, the vibration proof zoom lens system **102** has the same configuration as the vibration proof zoom lens **101** of the previous exemplary embodiment, except that the negative lens **50** of the fourth lens group is the negative meniscus lens with the convex surface toward the object side. In this case, the vibration proof zoom lens system **102** includes the same functions or operations as the vibration proof zoom lens system **101** of FIG. **3**A-**3**C.

Also, since the vibration proof zoom lens system **102** is adapted to the contrast detection type auto focus, it is possible for the photographing apparatus **110** of FIG. **2** to employ this lens system **102** as an alternative to the vibration proof zoom lens system **100**.

In the foregoing description, although the first part group of the third lens group has been explained as comprising one positive lens with the aspherical surface toward the image side, this is only an example. If the first part group is a part group with a positive refractive power and is configured to be simplified or weight-lightened thus to facilitate a very small displacement, it does not need to have the aspherical surface. In addition, even in the number of the lenses, the first part group can be configured to have, for example, more than two sheets.

Further, in the foregoing description, although the second part group of the third lens group has been explained as having the cemented lens comprising three lenses to form two cemented surfaces, it can be configured to have more than two cemented surfaces in order to correct the chromatic aberration well. For this, the second part group can have more than three lenses. For instance, the second part group can have two pairs of cemented lens, each of which comprise two cemented lenses, to form two cemented surfaces.

Furthermore, in the foregoing description, although the photographing apparatus using the vibration proof zoom lenses of the above described exemplary embodiments of the present inventive concept has been explained as the interchangeable lens camera, this is only an example, and the present inventive concept is not limited thereto. For instance, the photographing apparatus can be a built-in lens type camera, or a photographing apparatus, such as a video camera or the like.

Moreover, in the foregoing description, the number of the lenses or the arrangement and shape of the lens surfaces to form the positive and the negative refractive powers in each of the lens groups and the part groups is explained by way of showing examples only, and the present inventive concept is not limited thereto. In addition to the lens configurations of the exemplary embodiments as described above, it is possible to add proper lenses to each of the lens groups and the part groups if it is within the scope of technical spirit of the present inventive concept.

Also, all components explained in the exemplary embodiments of the present inventive concept can be embodied properly changing combinations or being properly deleting therefrom within the scope of technical spirit of the present inventive concept. For instance, aspects, desirable or preferable aspects and more preferable aspects embodied in the exemplary embodiments as described above can be embodied properly combining with each other.

EXAMPLE

Example 1

Next, an example 1, which is an example of a numerical value of the vibration proof zoom lens system **100** illustrated in the exemplary embodiment of FIGS. **1**A-**1**C as described above will be explained.

The below table shows configuration parameters of the vibration proof zoom lens system **100** of the example 1. A surface number j (j is a natural number) is distributed to each of surfaces of lenses forming the vibration proof zoom lens system **100**, respectively, so that the surface is increased toward the image side from a most object side lens surface to which a number 1 is assigned among surface of lenses forming the vibration proof zoom lens system **100**.

Further, a radius of curvature R_j is a radius of curvature of the lens surface corresponding to the surface number j, a surface clearance D_j is a surface clearance on an axis between a lens surface of the surface number j and a lens surface of the surface number j+1, and units are mm. For instance, the cemented surface **1***a* is a surface number 2, and the aspherical surface **7***a* is a surface number 16.

Also, refractive indexes η_d and υ_d represent a refractive index and an Abbe's number at a d line (wavelength of 587.56 nm) of each lens.

A shape of the aspherical surface, as a Sag's amount (a displacement amount in a direction of optical axis) x of a surface parallel to the optical axis O when an apex of the surface is of an origin and h is of a height from the optical axis O, is represented by the following formula 1.

[Formula 1]

$$x = \frac{Ch^2}{1+\sqrt{1-(1+K)C^2h^2}} + \sum_{i=2}^{5} A_{2i}h^{2i} \quad \text{(a)}$$

$$C = \frac{1}{R} \quad \text{(b)}$$

Here, C is represented by (b) of the above formula 1 when a curvature at an apex surface, that is, a radius of curvature on radical axis is of R. Further, K is a conic constant and A_{2i} (i=1, . . . , 5) are fourth, sixth, eighth, and tenth asphericities, respectively.

Surface number	Radius of curvature(R)	Surface clearance(D)	refractive index(η_d)	Abbe's number(ν_d)
1	R_1 = 111.479	D_1 = 1.50	η_1 = 1.80518	ν_1 = 25.5
2	R_2 = 61.309	D_2 = 7.60	η_2 = 1.49700	ν_2 = 81.6
3	R_3 = −426.398	D_3 = 0.15		
4	R_4 = 52.448	D_4 = 5.54	η_3 = 1.62041	ν_3 = 60.3
5	R_5 = 182.297	D_5 (Variable)		
6	R_6 = 141.166	D_6 = 1.30	η_4 = 1.83481	ν_4 = 42.7
7	R_7 = 14.181	D_7 = 5.96		
8	R_8 = −29.683	D_8 = 1.10	η_5 = 1.83481	ν_5 = 42.7
9	R_9 = 76.302	D_9 = 0.21		
10	R_{10} = 33.315	D_{10} = 5.38	η_6 = 1.84666	ν_6 = 23.8

-continued

11	$R_{11} = -24.432$	$D_{11} = 0.19$		
12	$R_{12} = -22.408$	$D_{12} = 1.00$	$\eta_7 = 1.80420$	$\nu_7 = 46.5$
13	$R_{13} = 214.014$	D_{13} (Variable)		
14	R_{14} = (Aperture)	D_{14} (Variable)		
15	$R_{15} = 37.571$	$D_{15} = 3.34$	$\eta_8 = 1.58673$	$\nu_8 = 61.3$
16	R_{16} (Aspherical surface)	D_{16} (Variable)		
17	$R_{17} = 18.038$	$D_{17} = 4.52$	$\eta_9 = 1.49700$	$\nu_9 = 81.6$
18	$R_{18} = -94.304$	$D_{18} = 0.90$	$\eta_{10} = 1.84666$	$\nu_{10} = 23.8$
19	$R_{19} = 25.723$	$D_{19} = 2.77$	$\eta_{11} = 1.51742$	$\nu_{11} = 52.2$
20	$R_{20} = -60.178$	$D_{20} = 2.50$		
21	R_{21} (Aspherical surface)	$D_{21} = 1.20$	$\eta_{12} = 1.69090$	$\nu_{12} = 53.3$
22	$R_{22} = 11.448$	$D_{22} = 2.88$	$\eta_{13} = 1.72825$	$\nu_{13} = 28.3$
23	$R_{23} = 23.631$	D_{23} (Variable)		
24	$R_{24} = 57.717$	$D_{24} = 4.42$	$\eta_{14} = 1.58123$	$\nu_{14} = 59.5$
25	R_{25} (Aspherical surface)	$D_{25} = 0.15$		
26	$R_{26} = 53.180$	$D_{26} = 7.35$	$\eta_{15} = 1.51742$	$\nu_{15} = 52.2$
27	$R_{27} = -15.655$	$D_{27} = 1.40$	$\eta_{16} = 1.83481$	$\nu_{16} = 42.7$
28	$R_{28} = 71.807$	$D_{28} = 0.25$		
29	$R_{29} = 42.883$	$D_{29} = 4.74$	$\eta_{17} = 1.58144$	$\nu_{17} = 40.9$
30	$R_{30} = -132.331$	D_{30} (Variable)		
31	$R_{31} = \infty$	$D_{31} = 2.24$	$\eta_{18} = 1.51633$	$\nu_{18} = 64.2$
32	$R_{32} = \infty$	$D_{32} = 0.60$		

[zoom data]

	Wide angle limit	Intermediate focal length	Telephoto limit
f(mm)	18.50	68.50	194.15
Fno	3.46	5.52	6.50
D_5	1.100	26.957	47.384
D_{13}	22.200	7.961	2.515
D_{14}	5.779	3.877	1.200
D_{16}	3.762	5.663	8.340
D_{23}	8.002	3.278	2.000
D_{30}	19.265	50.936	63.300

[Asphericity]

	R	K	A_4	A_6	A_8	A_{10}
R_{16}	−38.107	0.0	1.2499×10^{-5}	6.2648×10^{-10}	0.0	0.0
R_{21}	−51.272	0.0	1.8273×10^{-5}	-4.4695×10^{-8}	0.0	0.0
R_{25}	−36.580	0.0	1.1438×10^{-5}	5.6111×10^{-8}	-7.1015×10^{-11}	0.0

[Amount of focus movement of the first part group at object distance of 0.5 m]

Wide angle limit	Intermediate focal length	Telephoto limit
1.320	2.175	7.409

With the configuration as described above. As shown in the example 1 of the following table 1, calculation values corresponding to the condition equations (1) to (7) satisfy the condition equations (1) to (7), more particularly, (1a) to (7a), respectively.

TABLE 1

Condition equation	Calculation equation	Example 1	Example 2	Example 3
(1)	f_{3a}/f_t	0.168	0.190	0.192
(2)	f_{3b}/f_t	0.258	0.249	0.256
(3)	$\lvert f_{3c} \rvert/f_t$	0.123	0.147	0.156
(4)	f_{Ra}/f_t	0.152	0.185	0.181
(5)	f_{Rb}/f_t	0.220	0.227	0.238
(6)	f_1/f_t	0.435	0.434	0.444
(7)	$\lvert f_2 \rvert/f_t$	0.068	0.069	0.070
(8)	$\lvert f_{3f} \rvert/f_t$	—	1.524	1.396

Spherical aberrations, astigmatisms, distortion aberrations and transverse aberrations in the vibration proof by the vibration proof zoom lens **100** of the example 1 are illustrated in FIGS. **5** to **13**.

FIGS. **5**A-C, **6**A-C, **8**A-C, **9**A-C, **11**A-C, and **12**A-C, show spherical aberration graphs, astigmatism graphs, and distortion aberration graphs, respectively. FIGS. **5**A-**5**C and **6**A-**6**C represent aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the wide angle limit, respectively, FIGS. **8**A-**8**C and **9**A-**9**C represent aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the intermediate focal length, respectively, and FIGS. **11**A-**11**C and **12**A-**12**C represent aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the telephoto limit, respectively.

Units of transverse axis in the spherical aberration graphs and the astigmatism graphs are mm and units of transverse axis in the distortion aberration graphs are %. Further, units of vertical axis in the astigmatism graphs and the distortion aberration graphs are degree (deg.) (hereinafter, units in same aberration graphs are the same as above).

FIGS. **7**, **10** and **13** are aberration graphs showing transverse aberrations in the vibration proof at the wide angle limit, the intermediate focal length and the telephoto limit, respectively. In FIGS. **7**, **10**, and **13**, sections (a-1), (a-2) and (a-3) show transverse aberrations (mm) of meridional curves

at Y=10.0 (mm), Y=0 (mm) and Y=−10.0 (mm), respectively, and sections (b-1), (b-2) and (b-3) show transverse aberrations (mm) of sagittal curves corresponding to the transverse aberrations (mm) of meridional curves, respectively. Further, calculation conditions in the vibration proof are a vibration proof of 0.3 degree at a wavelength of 546.1 nm (hereinafter, calculation conditions in same aberration graphs are the same as above).

Furthermore, in the aberration graphs, solid lines, fine dotted lines, alternated long and short dash lines, alternated long and two short dashes lines and coarse fine dotted lines shows aberrations at wavelengths of 656.3 nm, 546.1 nm, 486.1 nm, 435.8 nm and 587.6 nm, respectively (hereinafter, lines in same aberration graphs are the same as above).

Also, the astigmatism graphs show the astigmatisms of the sagittal curves by thick curves designated by marks **ΔS1**, . . . , **ΔS1**, and the astigmatisms of the meridional curves by thin curves designated by marks **ΔM1**, . . . , **ΔM1**.

Referring to FIGS. **5**A to **13**, it can be appreciated that with the vibration proof zoom lens **100** of the present example, the spherical aberrations, the astigmatisms, and the distortion aberrations were well corrected within the object distance from the infinity to the 0.5 m at the wide angle limit, the intermediate focal length and the telephoto limit and at the same time, the transverse aberrations in the vibration proof were good.

Example 2

Next, an example 2, which is an example of numerical value of the vibration proof zoom lens system **101** illustrated in the exemplary embodiment of FIGS. **3**A-**3**C as described above will be explained.

The below table shows configuration parameters of the vibration proof zoom lens system **101** of the example 2. A surface number j (j is a natural number) is distributed in the same manner as in the example 1. For instance, the cemented surface **21***a* is a surface number 2, and the aspherical surface **27***a* is a surface number 18.

Surface number	Radius of curvature(R)	Surface clearance(D)	refractive index(η_d)	Abbe's number(ν_d)
1	R_1 = 108.692	D_1 = 1.50	η_1 = 1.80518	ν_1 = 25.5
2	R_2 = 59.849	D_2 = 8.13	η_2 = 1.49700	ν_2 = 81.6
3	R_3 = −431.693	D_3 = 0.15		
4	R_4 = 52.307	D_4 = 5.80	η_3 = 1.62041	ν_3 = 60.3
5	R_5 = 179.739	D_5 (Variable)		
6	R_6 = 141.166	D_6 = 1.30	η_4 = 1.83481	ν_4 = 42.7
7	R_7 = 13.905	D_7 = 5.96		
8	R_8 = −32.856	D_8 = 1.10	η_5 = 1.83481	ν_5 = 42.7
9	R_9 = 68.778	D_9 = 0.15		
10	R_{10} = 30.271	D_{10} = 5.54	η_6 = 1.84666	ν_6 = 23.8
11	R_{11} = −23.286	D_{11} = 0.14		
12	R_{12} = −21.908	D_{12} = 1.00	η_7 = 1.80420	ν_7 = 46.5
13	R_{13} = 138.173	D_{13} (Variable)		
14	R_{14} = −67.159	D_{14} = 1.20	η_8 = 1.74400	ν_8 = 44.9
15	R_{15} = −97.151	D_{15} = 1.00		
16	R_{16} (Aperture)	D_{16} (Variable)		
17	R_{17} = 37.586	D_{17} = 3.20	η_9 = 1.58673	ν_9 = 61.3
18	R_{18} = (Aspherical surface)	D_{18} (Variable)		
19	R_{19} = 17.435	D_{19} = 4.95	η_{10} = 1.49700	ν_{10} = 81.6
20	R_{20} = −58.546	D_{20} = 0.90	η_{11} = 1.84666	ν_{11} = 23.8
21	R_{21} = 38.554	D_{21} = 2.43	η_{12} = 1.51742	ν_{12} = 52.2
22	R_{22} = −83.758	D_{22} = 2.50		
23	R_{23} (Aspherical surface)	D_{23} = 1.20	η_{13} = 1.69090	ν_{13} = 53.3
24	R_{24} = 12.066	D_{24} = 2.87	η_{14} = 1.72825	ν_{14} = 28.3
25	R_{25} = 25.316	D_{25} (Variable)		
26	R_{26} = 25.223	D_{26} = 4.68	η_{15} = 1.53123	ν_{15} = 59.5
27	R_{27} (Aspherical surface)	D_{27} = 0.15		
28	R_{28} = 46.924	D_{28} = 7.57	η_{16} = 1.51742	ν_{16} = 52.2
29	R_{29} = −11.984	D_{29} = 1.40	η_{17} = 1.83481	ν_{17} = 42.7
30	R_{30} = 29.549	D_{30} = 0.43		
31	R_{31} = 27.366	D_{31} = 4.74	η_{18} = 1.58144	ν_{18} = 40.9
32	R_{32} = −91.492	D_{32} (Variable)		
33	R_{33} = ∞	D_{33} = 2.24	η_{18} = 1.51633	ν_{18} = 64.1
34	R_{34} = ∞	D_{32} = 0.60		

[zoom data]

	Wide angle limit	Intermediate focal length	Telephoto limit
f(mm)	18.50	68.50	194.15
Fno	3.55	5.81	6.50
D_5	1.100	26.203	48.034
D_{13}	19.455	6.684	1.916
D_{16}	6.812	4.301	1.200
D_{18}	2.288	4.799	7.900
D_{25}	6.328	3.191	2.000
D_{32}	20.757	52.134	60.319

-continued

[Asphericity]						
	R	K	A_4	A_6	A_8	A_{10}
R_{18}	−49.701	0.0	8.6468×10^{-6}	-6.0751×10^{-9}	0.0	0.0
R_{23}	−77.659	0.0	1.1980×10^{-5}	-3.0461×10^{-8}	0.0	0.0
R_{27}	−58.820	0.0	1.4007×10^{-5}	1.2894×10^{-8}	-9.8111×10^{-10}	0.0

[Amount of focus movement of the first part group at object distance of 0.5 m]		
Wide angle limit	Intermediate focal length	Telephoto limit
0.691	1.750	6.822

With the configuration as described above. As shown in the example 2 of the above table 1, calculation values corresponding to the condition equations (1) to (8) satisfy the condition equations (1) to (8), more particularly, (1a) to (8a), respectively.

Spherical aberrations, astigmatisms, distortion aberrations and transverse aberrations in the vibration proof by the vibration proof zoom lens **101** of the present example are illustrated in FIGS. **14**A to **22**.

FIGS. **14**A-C, **15**A-C, **17**A-C, **18**A-C, **20**A-C, and **21**A-C show spherical aberration graphs, astigmatism graphs, and distortion aberration graphs, respectively. FIGS. **14**A-**14**C and **15**A-**15**C represent aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the wide angle limit, respectively, FIGS. **17**A-**17**C and **18**A-**18**C represent aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the intermediate focal length, respectively, and FIGS. **20**A-**20**C and **21**A-**21**C represent aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the telephoto limit, respectively.

FIGS. **16**, **19** and **22** are aberration graphs showing transverse aberrations in the vibration proof at the wide angle limit, the intermediate focal length and the telephoto limit, respectively.

Referring to FIGS. **14**A to **22**, it can be appreciated that with the vibration proof zoom lens **101** of the present example, the spherical aberrations, the astigmatisms, and the distortion aberrations were well corrected within the object distance from the infinity to the 0.5 m at the wide angle limit, the intermediate focal length and the telephoto limit and at the same time, the transverse aberrations in the vibration proof were good.

Example 3

Next, an example 3, which is an example of numerical value of the vibration proof zoom lens system **102** illustrated in the exemplary embodiment of FIGS. **4**A-**4**C as described above will be explained.

The below table shows configuration parameters of the vibration proof zoom lens system **102** of the example 3. A surface number j (j is a natural number) is distributed in the same manner as in the example 1. For instance, the cemented surface **41***a* is a surface number 2, and the aspherical surface **47***a* is a surface number 18.

Surface number	Radius of curvature(R)	Surface clearance(D)	refractive index(η_d)	Abbe's number(ν_d)
1	$R_1 = 97.141$	$D_1 = 1.50$	$\eta_1 = 1.80518$	$\nu_1 = 25.4$
2	$R_2 = 59.007$	$D_2 = 7.88$	$\eta_2 = 1.49700$	$\nu_2 = 81.6$
3	$R_3 = -800.000$	$D_3 = 0.15$		
4	$R_4 = 53.855$	$D_4 = 5.70$	$\eta_3 = 1.59282$	$\nu_3 = 68.6$
5	$R_5 = 191.269$	D_5 (Variable)		
6	$R_6 = 142.685$	$D_6 = 1.30$	$\eta_4 = 1.83481$	$\nu_4 = 42.7$
7	$R_7 = 14.165$	$D_7 = 6.19$		
8	$R_8 = -38.401$	$D_8 = 1.10$	$\eta_5 = 1.83481$	$\nu_5 = 42.7$
9	$R_9 = 56.480$	$D_9 = 0.15$		
10	$R_{10} = 27.550$	$D_{10} = 5.70$	$\eta_6 = 1.84666$	$\nu_6 = 23.8$
11	$R_{11} = -27.550$	$D_{11} = 0.26$		
12	$R_{12} = -24.275$	$D_{12} = 1.00$	$\eta_7 = 1.80420$	$\nu_7 = 46.5$
13	$R_{13} = 126.878$	D_{13} (Variable)		
14	$R_{14} = 366.767$	$D_{14} = 1.20$	$\eta_8 = 1.74400$	$\nu_8 = 44.9$
15	$R_{15} = 130.359$	$D_{15} = 1.43$		
16	R_{16} (Aperture)	D_{16} (Variable)		
17	$R_{17} = 42.013$	$D_{17} = 3.15$	$\eta_9 = 1.58673$	$\nu_9 = 61.3$
18	R_{18} = (Aspherical surface)	D_{18} (Variable)		
19	$R_{19} = 16.032$	$D_{19} = 4.82$	$\eta_{10} = 1.49700$	$\nu_{10} = 81.6$
20	$R_{20} = -193.374$	$D_{20} = 0.90$	$\eta_{11} = 1.8666$	$\nu_{11} = 23.8$
21	$R_{21} = 30.530$	$D_{21} = 2.39$	$\eta_{12} = 1.48749$	$\nu_{12} = 70.4$
22	$R_{22} = -319.245$	$D_{22} = 2.62$		
23	R_{23} (Aspherical surface)	$D_{23} = 1.20$	$\eta_{13} = 1.69090$	$\nu_{13} = 53.3$
24	$R_{24} = 12.048$	$D_{24} = 2.97$	$\eta_{14} = 1.69895$	$\nu_{14} = 30.1$
25	$R_{25} = 26.462$	D_{25} (Variable)		
26	$R_{26} = 27.692$	$D_{26} = 4.45$	$\eta_{15} = 1.58123$	$\nu_{15} = 59.5$
27	R_{27} (Aspherical surface)	$D_{27} = 0.15$		
28	$R_{28} = 53.280$	$D_{28} = 7.03$	$\eta_{16} = 1.53172$	$\nu_{16} = 48.8$
29	$R_{29} = -12.400$	$D_{29} = 1.40$	$\eta_{17} = 1.83481$	$\nu_{17} = 42.7$

-continued

30	R_{30} = 32.417	D_{30} = 0.27		
31	R_{31} = 26.783	D_{31} = 4.30	η_{18} = 1.59551	ν_{18} = 39.2
32	R_{32} = −294.154	D_{32} (Variable)		
33	R_{33} = ∞	D_{33} = 2.24	η_{18} = 1.51633	ν_{18} = 64.1
34	R_{34} = ∞	D_{32} = 0.60		

[zoom data]

	Wide angle limit	Intermediate focal length	Telephoto limit
f(mm)	18.50	68.50	194.15
Fno	3.52	5.62	6.50
D_5	1.100	27.358	48.606
D_{13}	20.647	3.627	1.514
D_{16}	6.096	6.755	1.200
D_{18}	3.588	2.929	8.484
D_{25}	5.624	3.300	2.000
D_{32}	20.368	49.382	60.156

[Asphericity]

	R	K	A_4	A_6	A_8	A_{10}
R_{18}	−44.530	0.0	9.0354×10^{-6}	-2.3869×10^{-9}	0.0	0.0
R_{23}	−102.580	0.0	1.2632×10^{-5}	-3.6389×10^{-8}	0.0	0.0
R_{25}	−50.974	0.0	2.0732×10^{-5}	5.6406×10^{-8}	-6.0181×10^{-10}	0.0

[Amount of focus movement of the first part group at object distance of 0.5 m]

Wide angle limit	Intermediate focal length	Telephoto limit
0.692	1.852	6.762

With the configuration as described above. As shown in the example 3 of the above table 1, calculation values corresponding to the condition equations (1) to (8) satisfy the condition equations (1) to (8), more particularly, (1a) to (8a), respectively.

Spherical aberrations, astigmatisms, distortion aberrations and transverse aberrations in the vibration proof by the vibration proof zoom lens **102** of the present example are illustrated in FIGS. **23** to **31**.

FIGS. **23**A-C, **24**A-C, **26**A-C, **27**A-C, **29**A-C, and **30**A-C show spherical aberration graphs, astigmatism graphs, and distortion aberration graphs, respectively. FIGS. **23**A-**23**C and **24**A-**24**C show aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the wide angle limit, respectively, FIGS. **26**A-**26**C and **27**A-**27**C show aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the intermediate focal length, respectively, and FIGS. **29**A-**29**C and **30**A-**30**C show aberrations at the time of focusing the infinity objection distance and the objection distance of 0.5 mm at the telephoto limit, respectively.

FIGS. **25**, **28** and **31** include aberration graphs showing transverse aberrations in the vibration proof operations at the wide angle limit, the intermediate focal length and the telephoto limit, respectively.

Referring to FIGS. **23**A to **31**, it can be appreciated that with the vibration proof zoom lens **102** (see FIGS. **4**A-**4**C) of the present example, the spherical aberrations, the astigmatisms, and the distortion aberrations were well corrected within the object distance from the infinity to the 0.5 m at the wide angle limit, the intermediate focal length and the telephoto limit and at the same time, the transverse aberrations in the vibration proof were good.

Although various embodiments of the present inventive concept have been explained by the exemplary embodiments and drawings as described above, it is not limited to the foregoing exemplary embodiments. The present teaching can be readily applied to other types of apparatuses and many, alternatives, modifications, and variations will be apparent to those skilled in the art.

Thus, the scope of the present inventive concept is not to be construed as being limited to the description of the exemplary embodiments, and is to be construed by the attached claims and equivalents.

What is claimed is:

1. A vibration proof zoom lens, comprising a first lens group with a positive refractive power, a second lens group with a negative refractive power, and a succeeding group having a positive refractive power as a whole, which are arranged in order from an object side of the lens,

wherein the succeeding group has a first part group with a positive refractive power, a second part group with a positive refractive power, the second part group comprising more than one cemented lens to form at least two cemented surfaces, and a third part group with a negative refractive power, which are disposed in order from the object side of the lens,

wherein in variable-magnifying from a wide angle limit to a telephoto limit, a clearance between the first lens group and the second lens group is increased and at the same time, a clearance between the second lens group and the succeeding group is decreased,

wherein a focusing from an infinity side to a close side is performed by moving the first part group toward an image side of the lens,

wherein a vibration proof operation is performed by moving the third part group in a direction perpendicular to an optical axis to change an image position, and

wherein the following condition equations (1), (2) and (3) are satisfied:

$$0.1<f_{3a}/f_t<0.3 \quad (1)$$

$$0.15<f_{3b}/f_t<0.35 \quad (2)$$

$$0.05<|f_{3c}|/f_t<0.25 \quad (3)$$

where f_{3a} is a focal length of the first part group, f_{3b} is a focal length of the second part group, f_{3c} is a focal length of the third part group, and f_t is a focal length of all systems at the telephoto limit.

2. The lens of claim **1**, wherein the second part group comprises a cemented lens consisting of two positive lenses and one negative lens.

3. The lens of claim **1**, wherein the third part group comprises one negative lens and one positive lens.

4. The lens of claim **1**, wherein the succeeding group comprises:

a third lens group comprising the first part group, the second part group and the third part group; and

a fourth lens group disposed on an upper side of the third lens group, the fourth lens group having a positive refractive power and changing an air space of the image side in the variable-magnifying,

wherein in the variable-magnifying from the wide angle limit to the telephoto limit, a clearance between the third lens group and the fourth lens group is decreased, and

wherein the following condition equations (4) and (5) are satisfied:

$$0.05<f_{Ra}/f_t<0.3 \quad (4)$$

$$0.1<f_{Rb}/f_t<0.35 \quad (5)$$

where f_{Ra} is a focal length of the third lens group at the telephoto limit and f_{Rb} is a focal length of the fourth lens group.

5. The lens of claim **1**,

wherein the first lens group comprises one positive lens, which has an aspherical surface with a positive refractive power becoming smaller as getting away from the optical axis.

6. The lens of claim **1**,

wherein in the variable-magnifying from the wide angle limit to the telephoto limit, a clearance between the first part group and the second part group is increased.

7. The lens of claim **1**, wherein the following condition equations (6) and (7) are satisfied:

$$0.25<f_1/f_t<0.65 \quad (6)$$

$$0.04<|f_2|/f_t<0.1 \quad (7)$$

where f_1 is a focal length of the first lens group and f_2 is a focal length of the second lens group.

8. The lens of claim **1**,

wherein the third lens group further comprises a fourth part group having a negative refractive power at an object side of the first part group,

wherein the following condition equation (8) is satisfied:

$$0.5<|f_{3f}|/f_t<5.0 \quad (8)$$

here, f_{3f} is a focal length of the fourth part group.

9. The lens of claim **8**, wherein the fourth part group comprises a negative lens.

10. The lens of claim **8**, wherein the fourth part group comprises a negative meniscus lens having a convex surface toward the object side.

11. The lens of claim **2**, wherein the third part group comprises one negative lens and one positive lens.

12. The lens of claim **2**, wherein the succeeding group comprises:

a third lens group comprising the first part group, the second part group and the third part group; and

a fourth lens group disposed on an upper side of the third lens group, the fourth lens group having a positive refractive power and changing an air space of the image side in the variable-magnifying,

wherein in the variable-magnifying from the wide angle limit to the telephoto limit, a clearance between the third lens group and the fourth lens group is decreased, and

wherein the following condition equations (4) and (5) are satisfied:

$$0.05<f_{Ra}/f_t<0.3 \quad (4)$$

$$0.1<f_{Rb}/f_t<0.35 \quad (5)$$

where f_{Ra} is a focal length of the third lens group at the telephoto limit and f_{Rb} is a focal length of the fourth lens group.

13. A photographing apparatus comprising a vibration proof zoom lens comprising: a first lens group with a positive refractive power; a second lens group with a negative refractive power; and a succeeding group having a positive refractive power as a whole, which are arranged in order from an object side of the lens,

wherein the succeeding group has a first part group with a positive refractive power, a second part group with a positive refractive power, the second part group comprising more than one cemented lens to form at least two cemented surfaces, and a third part group with a negative refractive power, which are disposed in order from the object side,

wherein in variable-magnifying from a wide angle limit to a telephoto limit, a clearance between the first lens group and the second lens group is increased and at the same time, a clearance between the second lens group and the succeeding group is decreased,

wherein a focusing from an infinity side to a close side is performed by moving the first part group toward an image side,

wherein a vibration proof operation is performed by moving the third part group in a direction perpendicular to an optical axis to change an image position, and

wherein the following condition equations (1), (2) and (3) are satisfied:

$$0.1<f_{3a}/f_t<0.3 \quad (1)$$

$$0.15<f_{3b}/f_t<0.35 \quad (2)$$

$$0.05<|f_{3c}|/f_t<0.25 \quad (3)$$

where f_{3a} is a focal length of the first part group, f_{3b} is a focal length of the second part group, f_{3c} is a focal length of the third part group, and f_t is a focal length of all systems at the telephoto limit.

14. A vibration proof zoom lens having an object side and an image side, comprising:

a first lens group with a positive refractive power and facing an object side of the lens system;

a second lens group with a negative refractive power disposed between the first lens group and the image side; and

a succeeding group having a positive refractive power as a whole and disposed between the second lens group and the image side, the succeeding group including:

a first part group with a positive refractive power,

a second part group with a positive refractive power, the second part group comprising more than one cemented lens to form at least two cemented surfaces and diposed between the first part group and the image side, and

a third part group with a negative refractive power and disposed between the second part group and the image side,

wherein in variable-magnifying from a wide angle limit to a telephoto limit, a clearance between the first lens group and the second lens group is increased and at the same time, a clearance between the second lens group and the succeeding group is decreased,

wherein a focusing from an infinity side to a close side is performed by moving the first part group toward an image side of the lens,

wherein a vibration proof operation is performed by moving the third part group in a direction perpendicular to an optical axis to change an image position, and

wherein the following condition equations (1), (2) and (3) are satisfied:

$$0.1<f_{3a}/f_t<0.3 \quad (1)$$

$$0.15<f_{3b}/f_t<0.35 \quad (2)$$

$$0.05<|f_{3c}|/f_t<0.25 \quad (3)$$

where f_{3a} is a focal length of the first part group, f_{3b} is a focal length of the second part group, f_{3c} is a focal length of the third part group, and f_t is a focal length of all systems at the telephoto limit.

15. The lens of claim **14**, wherein the succeeding group comprises:

a third lens group comprising the first part group, the second part group and the third part group; and

a fourth lens group disposed between the third lens group and the image side, the fourth lens group having a positive refractive power and changing an air space of the image side in the variable-magnifying,

wherein in the variable-magnifying from the wide angle limit to the telephoto limit, a clearance between the third lens group and the fourth lens group is decreased, and

wherein the following condition equations (4) and (5) are satisfied:

$$0.05<f_{Ra}/f_t<0.3 \quad (4)$$

$$0.1<f_{Rb}/f_t<0.35 \quad (5)$$

where f_{Ra} is a focal length of the third lens group at the telephoto limit and fR_b is a focal length of the fourth lens group.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,140,905 B2
APPLICATION NO. : 13/332742
DATED : September 22, 2015
INVENTOR(S) : Misaka

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the claims

Claim 14, Column 29, Line 5

Delete "diposed" and insert --disposed--, therefor.

Claim 14, Column 29, Line 27

Delete "$0.05 < IIf_{3c} I/f_t < 0.25$" and insert --$0.05 < If_{3c} I /f_t < 0.25$--, therefor.

Claim 15, Column 30, Line 25

Delete "limit and fRb" and insert --limit and f_{Rb}--, therefor.

Signed and Sealed this
Fifteenth Day of December, 2015

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office